MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

American Aeronautics

In scientific and engineering progress in aviation, more particularly in heavier-than-air machines, the United States now leads the world. In the development of commercial aviation by private initiative, however, the United States is lagging far behind other countries. It suffers on one hand from the representations of enthusiastic promoters whose claims arouse suspicion; on the other hand from a general indifference due to ignorance of what has been actually accomplished, of the development, reliability, safety, etc. of commercial aviation in Europe and of the services which aircraft can render to modern business.

(Extract from the report by a special committee of the American Engineering Council. As the result of the report the American Engineering Council is now conducting an investigation to make public present knowledge and to develop new facts by which advance in American aeronautics may be assisted.)

JULY 1925

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D. J. McAdam, Jr.

Spencer Miller

William Rankine Eckart

H. H. Hall

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* * * * *

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* * * * *

The symposium presented in this issue on The Utilization of Wood Waste as Fuel in Steam Power Plants, comprises papers by **H. W. Beecher, C. C. Simeral, C. L. Young** and **A. C. Sullivan.** Mr. Beecher, who writes on Combustion of Wood Waste from Lumber-Manufacturing Plants, is manager of the Seattle, Wash., offices of Chas. C. Moore & Co. and the Babcock & Wilcox Co. He received his B.S. from the University of California in 1906 and from that time has been associated with Chas. C. Moore & Co. He has recently become connected with the Babcock & Wicox Co. Mr. Simeral, author of Boiler-Room Operation of Wood-Refuse-Fired Steam Plants, is assistant superintendent of steam power plants of the Portland Electric Power Co. He has been connected since 1911 with the Portland Railway, Light & Power Co., now the Portland Electric Power Co. where he has charge of operation, maintenance, boiler testing, etc. Mr. Young, whose paper deals with Settings for Hog-Fuel Burning Boilers, is of the firm of Johnston & Young, Portland, Ore. Mr. Sullivan, author of the paper on Hog-Fuel Conveyors, is northwest manager of the Chain Belt Co., Portland, Ore. Mr. Sullivan was graduated in 1906 from the University of Washington as a mechanical engineer. He was formerly connected with the Allis-Chalmers Manufacturing Co., and with the Smith & Watson Iron Works.

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Earle Buckingham, engineer with the Niles-Bement-Pond Co., New York, writes on Engineering Standards. Mr. Buckingham attended the United States Naval Academy from 1904 to 1906. He has been associated with the Winchester Repeating Arms Co., the Veeder Manufacturing Co., the Royal Typewriter Co. and the Canadian Car & Foundry Co. During the War, Mr. Buckingham served in the Ordnance Department of the U. S. Army, holding successively the commissions of captain and major. After the War he became connected with the Pratt & Whitney Co., Hartford, Conn. He is at present with the Niles-Bement-Pond Co. Since 1920 he has been a member of the National Screw Thread Commission.

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W. A. Shoudy, co-author with Mr. Denny of Recent Developments in the Burning of Anthracite, was graduated from Stevens Institute of Technology in 1899, and later was assistant professor of engineering practice there. He also served as assistant mechanical engineer for the J. G. White Engineering Corporation and as power engineer for the American Sugar Refining Co. He has been identified with central-station design and operation since 1913. At present Mr. Shoudy is advisory engineer of the Adirondack Power & Light Corporation, consulting engineer of the Bailey Meter Co., and associate in mechanical engineering at Columbia University.

* * * *

R. C. Denny, co-author with Mr. Shoudy of the paper on Recent Developments in the Burning of Anthracite, was graduated from Cornell University as a mechanical engineer. During the past ten years he has devoted his time almost entirely to combustion problems, especially to the burning of anthracite. He worked on these problems for Colgate & Co. for several years and in 1919 entered the employ of the Combustion Engineering Corporation, where he is now a member of the test and research department. During a part of this period Mr. Denny was technical editor of *Combustion*.

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D. J. McAdam, Jr., author of the paper on Endurance Properties of Metals, received the degrees of A.B. and A.M. from Washington and Jefferson College. He spent two years in post-graduate study of chemistry at Harvard and two years at the University of Pennsylvania. He received the degrees of M.S. and Ph.D. from the latter institution. After several years spent in teaching chemistry at Lehigh University and in several other positions, he assumed his present position as metallurgist at the U. S. Naval Engineering Experiment Station, Annapolis, Md. He is a member of several technical and scientific societies and author of a number of papers on metallurgy.

MECHANICAL ENGINEERING

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The Overhead-Cableway Method of Logging

The First Logging Cableway—Evolution of the Mechanical Slackpuller—The Portable-Spar Skidder And Its Operation

By SPENCER MILLER,[1] NEW YORK, N. Y.

THIS paper records the development of the overhead cableway method of logging during the last forty years. The cableway, a hoisting and conveying device, employs a single-span cable as a trackway, and when adapted for logging is called an overhead skidder, "skidding" in logging operations meaning hauling. Most of the large logging operations today involve the construction of railroads into the timber lands. The overhead-cableway skidder is an auxiliary transporting apparatus acting as a feeder to the railroads; it may reach out 3000 or even 5000 ft. from the track, depending upon ground conditions, and has proven to be the cheapest method for logging, especially out of swamps and in mountain tracts where railroad building is costly.

The first cableway skidders were rigged to standing trees, using manila ropes for the operating lines. Today the latest development employs a portable power plant on a single platform carrying a 100-ft. raising and lowering spar to which the necessary pulley blocks and guys are permanently attached, and also carrying a loading crane. Wire rope is used throughout. These power plants weigh and cost twenty times as much as the first cableway skidder. This machine is called the "portable-steel-spar cableway skidder," and is generally operated by steam power. Two recently constructed cableway skidders, of the tree-rigged type, are operated by electric motors.

To indicate the extent of the development during the last 40 years the following comparisons are made.

	First Cableway Skidder	Latest Type of Plant
Power plant, weight, about	15,000 lb.	300,000 lb.
Main cable	$^3/_4$ in.	$1^3/_4$ in.
Span	650 ft.	5000 ft.
Total amount of wire rope	3000 ft.	32,000 ft.
Load carried	3 tons	25 tons
Daily maximum output, about	20,000 ft.	250,000 ft.

An overhead-cableway skidder reaching out 2000 ft. requires about six miles of wire rope. The main cable or trackway generally employed in a cableway for logging has about one-half the strength of a corresponding main cable attached to fixed towers for carrying equal loads, but the cableway skidder in its entirety is inherently elastic, and the safety of the apparatus is chiefly traceable to its elasticity. When the main cable is carrying its maximum load it elongates elastically, the trees to which it is attached, the guys, and the stumps employed for anchorage all yield automatically in proportion to the load and thus prevent overstresses in the cable. The "choker" attaching the log to the hoisting rope (called "skidding line") is the weakest link in the system and is the first to break, thus contributing to the safety of the whole cableway skidder.

Good management is necessary for efficient operation with cableway skidders, and to obtain the most economical operation much consideration must be given to the location of railroads and settings of the skidder.

It is generally recognized that the overhead-cableway skidding method leaves the forest in a better condition for future forest growth than the conventional ground-hauling methods.

The subject of electric logging is assigned to another writer. Two electric long-span, tree-rigged cableway skidders have been in practical use many months, but aside from the employment of electric motors in place of steam engines, the cableways are the same as described herein.

The ever-increasing employment of the portable-steel-spar cableway skidder, which is the most costly logging machine and one representing the highest engineering development in the logging art, speaks volumes for its efficiency.

Early History

The cableway is of modern origin, although an essential element, wire rope, was actually made before the Christian era. When the city of Pompeii, which was destroyed in the year 79 B.C., was uncovered, about fifteen feet of 3-strand bronze wire rope $^1/_2$ in. in diameter was found. This rope is now in the museum at Naples, Italy.

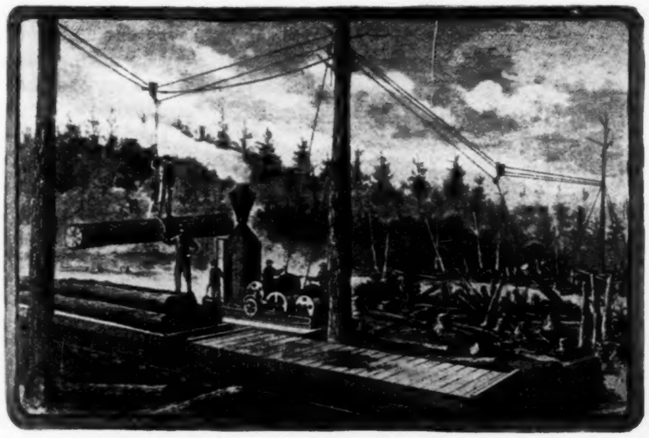

Fig. 1 The First Logging Cableway

The wire-rope tramway, more than two and a half centuries old, the forerunner of the cableway, was designed by Adam Wybe, a Dutch engineer, and erected in Dantzic, Germany, in 1644.

The cableway as a hoisting and conveying device was first shown in print in a French patent granted to Pluchet, January 4, 1851.

An American, W. H. Brown, four years later patented an interesting form of cableway for the construction of bridge piers. In 1860 Charles Schumann, of Pennsylvania, constructed a single-rope inclined cableway for short spans, many duplicates of which have been introduced in slate quarries.

Several horizontal cableways similar to the modern type were constructed and operated in Grafton, Ill., in 1868–1869. Each of these comprised a main cable as a trackway, an endless rope to propel the load carriage, a hoisting rope, and fall-rope carriers to support the sag in the hoist rope when slack.

In 1871, and possibly earlier, John Fyfe, of Aberdeenshire, Scotland, made a striking improvement in the cableway by leading the main cable over a sheave of large diameter in the tower and then dropping it vertically, a weight representing the maximum stress on the cable being attached to its end. This idea has been frequently employed in the United States.

In 1880 Alexander E. Brown, of Cleveland, Ohio, constructed

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several short-span cableways for discharging iron ore from vessels. One tower had an overhanging boom to reach over the ship. Both towers traveled on railroad tracks.

The First Logging Cableway

In 1883 the first wire-rope logging device (Fig. 1) was developed by Horace Butters, a pine lumberman. He constructed an overhead logging cableway in Ludington, Mich. A special 7-in. by 10-in. double cylinder Lidgerwood hoist with boiler and with three friction drums (weight 13,000 lb.) to operate this cableway was purchased. Mr. Butters rigged his cableway to standing trees instead of towers, and actually hoisted and hauled logs from the woods and loaded them on railroad cars. In spite of the antiquity of wire rope, it may surprise one to learn that his earlier logging cableways employed manila rope for the operating lines and guys, and for a short while even as a main cable. The zeal and determination of this enterprising lumberman put this overhead-cableway skidder in practical operation, and while hardly a commercial success in pine logging, nevertheless it attracted the attention of cypress lumbermen in the swamps of North Carolina and Louisiana.

The second phase in the development of the cableway method for logging occurred in the year 1892 in the South, where the problem of logging out of cypress swamps was in great need of solution. It was found necessary to redesign every element of the cableway skidder, such as engine, boiler, rigging, traveling carriages, special pulley blocks, lacking a full knowledge of the logger's problems. From that time and for a few years thereafter, the progress was one of evolution rather than creation. The first machines were too light to handle cypress logs; breakages were frequent and delays costly. These machines were carefully studied by the author, who sought to improve them by taking account of failures and correcting subsequent machines. In spite of frequent breakdowns these early machines would in a few months earn for their owners as much as the machines had cost.

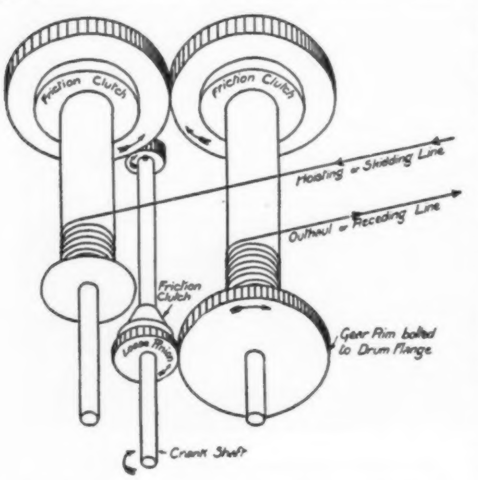

Fig. 2 Interlocking Drum Arrangement for Cableway Skidder

In all logging cableways an outhaul rope, operated by a friction drum, is necessary to haul the load carriage to the woods. The hoisting or skidding rope is operated by a second friction drum. The skidding rope leads through a pulley block on a head-spar tree, then through to another block on the carriage, and then to the log, to which it is attached. In the early logging cableways, after the log was hoisted to the carriage, the carriage and log were hauled in by the skidding rope, while simultaneously the outhaul rope was paid out through the drag of a brake on the outhaul friction drum. This was inefficient and was a source of much delay.

In 1900, the author, associated with J. H. Dickinson, of New York, invented an improved overhead skidder with much greater power and greater speed and which remedied these difficulties. The drag of the outhaul brake was eliminated. This new design contained many other features that made for efficiency and labor saving, and has been commercially known for years as the "interlocking and slackpulling cableway skidder." This machine, originally built for 800-ft. spans, was so revolutionary in character that it is worthy of description: it was the forerunner of the modern overhead logging cableway in general use and made by several manufacturers.

Interlocking Drums. The interlocking feature was a simple combination of gearing with two friction drums and one friction clutch. (Fig. 2.) When the skidding drum and outhaul drum were in friction engagement with appropriate gears, the outhaul drum would run in the opposite direction at the same speed at which the inhaul or skidding rope was wound in. When the log was delivered to the railroad, both drums were thrown out of friction and a third friction clutch on the crankshaft was thrown into engagement with a loose gear on the same shaft which, meshing with a rim gear on the outhaul drum, revolved it in the reverse direction at high speed. Thus it propelled the load carriage out into the timber at more than three times the speed of former machines. This new type displaced the original machines in many logging camps because it conserved power, increased speed, and eliminated the drag of any brake.

Fall-rope carriers to support the slackened skidding line were found impracticable for logging cableways, and the branch-rope device, patented first by the author in 1893 and again in another form by J. H. Dickinson in 1895, was adopted in 1900.

Fig. 3 Pulling Slack by Hand

Evolution of the Slackpuller

No single item of the cableway skidder is of greater importance than the slackpuller. Its cost is trifling, it saves many men, and it increases the output. No modern cableway skidder is complete without it, and its evolution is illustrated in the sketches grouped in Fig. 4.

The first mechanical slackpuller was invented by the author in 1891. It employed a small rope leading from a special friction drum on the engine to the head spar, thence to the tail spar about a sheave, and back again to a point where it was spliced into the hoisting or skidding line. The function of this device was to pull the skidding rope out from the engine and permit the hook and chokers on the free end of the skidding line to slack away and lower to the ground. It was first used on a stationary cableway, but gave trouble because the natural rotation of the ropes twisted them one about the other.

Two years later J. H. Dickinson improved the slackpuller by moving the sheave wheel from the tail tree and attaching it to the carriage. The improved device was first used in logging operations. To prevent twisting, the skidding and slackpulling ropes were laid along the railroad track and given a strong pull which deadened or "set" them somewhat.

In 1896 William Baptist, a practical logger, added a swivel in the skidding line, attaching the slackpulling line to this swivel. This was not very successful.

Ten years later John H. Shay, of Louisiana, working in a lumber camp, devised what is commercially known today as the Shay swivel. His invention in fact comprised two swivels properly installed, in which the skidding line leads straight through a loose tubular fitting provided with a lug. Stops on the line prevent its moving toward the head spar. The slackpulling line is attached to the lug, a swivel being introduced in the smaller line as shown in Fig. 4. By this means both the skidding line and slackpulling line can twist and revolve quite harmlessly.

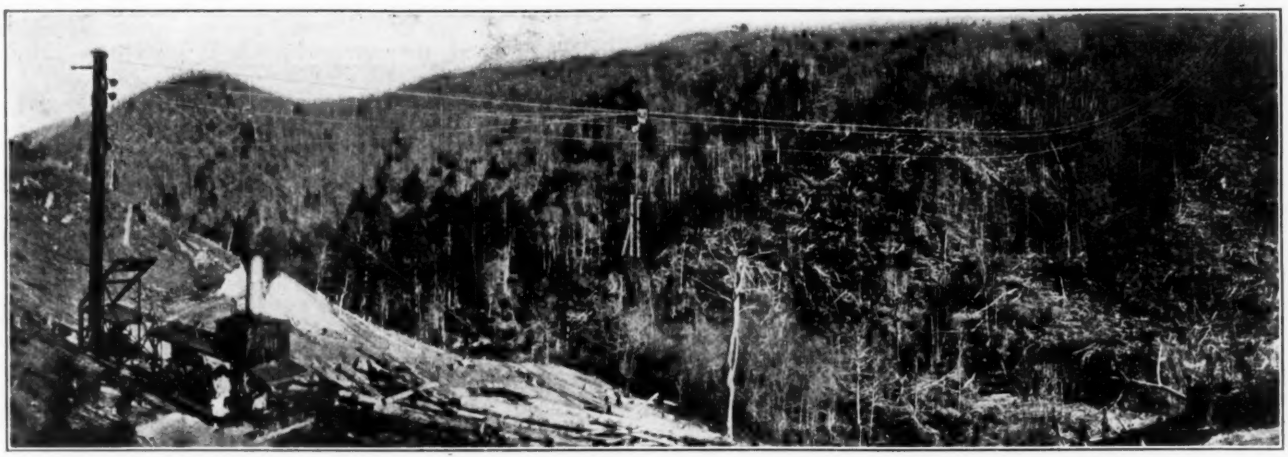

FIG. 5 OVERHEAD-CABLEWAY SKIDDER OF THE HIGH STEEL-SPAR TYPE OPERATING OVER A 3800-FT. SPAN

The slackpulling line is absolutely essential for long-span logging and saves the labor of several men to pull slack by hand, besides which the operation is much quicker. The saving effected by this simple invention, that is to say, the mechanical slackpuller, amounts to at least $50 a day on long-span cableways.

Economic Gain. Before the adoption of the cableway skidder in cypress logging, choice cypress swamps, estimated to carry 30,000 ft. to the acre, were bought at $1 per acre. Inferior cypress lands today command $100 per acre. Before the introduction of the cableway skidder, logs at the mill cost from $8 per thousand upward, common labor then obtaining $1.25 per day for 12 hours' work, and the supply was so intermittent as to prevent the building of large and economical sawmills. After its adoption a regular supply of logs was available and at less than half this cost.

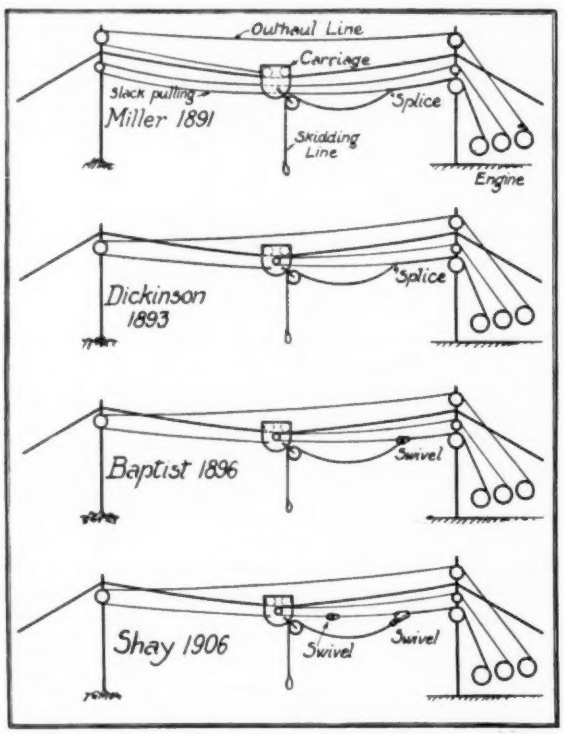

FIG. 4 EVOLUTION OF THE MECHANICAL SLACKPULLER

Logging on the Pacific Coast

Lumbermen on the Pacific Coast began to use steam power very early for the ground haulage of logs. Many clever machines were produced for this purpose. The first of these overhead-cableway skidders for the Pacific Coast was operated by the Kerry Mill Co. in 1904, 21 years ago. This machine, still in daily operation, is similar to those used in cypress logging. Later on cableway skidders for the Pacific Coast were made much heavier and with longer spans. In fact, at present overhead skidders handle logs $2^1/_2$ times as heavy as the earlier machines. A "million feet a month" was a wonderful output in the early days. Today portable-spar cableway skidders have averaged three and a third million board feet per month for ten consecutive months, while outputs of four and a half million monthly have actually been attained by several operators.

Pacific Coast logging cableways have not yet equaled the long-span cableways employed in the mountains of North Carolina, Tennessee, and West Virginia. These cableways, regularly designed for spans of 4000 ft., have been stretched out to spans of 5000 ft. Such cableways, however, handle small logs. Generally speaking, spans exceeding 3000 ft. are not profitable to employ on the Pacific Coast. The daily output of a cableway skidder becomes less as the span is increased.

Long Spans—Spars or Towers

The development of overhead-cableway skidders on the Pacific Coast went hand in hand with the development of the long-span Appalachian Mountain cableways referred to. The most notable of these, used by the Suncrest Lumber Company in North Carolina, is shown in Fig. 6. The novel features, which have already been described, reside in the steel spar 82 ft. high and the main cable reel using only one main cable instead of two. It is clear that while the double-cable system was found ideal for cypress swamps and is still the popular form, it could not be thought of for spans of 4000 or 5000 ft. where the spans are variable.

Several forms of steel spars to meet the various problems presented have been constructed, namely,

1 The plain pole
2 The fixed 4-post tower mounted on a car, with no means of lowering same. 1908
3 The portable spar pivoted to a tower located on a portable platform. 1911
4 The steel spar pivoted at its base with the single main-cable system, first introduced in 1912.

It is hardly necessary in a paper of this character to dwell at length on the various intermediate steps taken, and the author will therefore describe the latest developments in logging machines which represent the greatest progress from an engineering standpoint.

The Portable-Steel-Spar Skidder

During 1924 several portable-spar skidders with spars 100 ft. high were constructed. (See Fig. 6.) The total weight of these skidders without wire rope is about 300,000 lb. The skidder power plant is mounted on a steel platform about 60 ft. long and 14 ft. wide, which is supported by legs and blocking straddling the track, permitting the passage of empty cars underneath. When the track is a through line the power plant is set on a siding. The raising and lowering spar is supported by a universal trunnion mounted in a tower on the platform. The platform carries a vertical tubular boiler, a 5-drum cableway-skidder engine, a 4-drum utility engine for rigging purposes, and a third or guy-line engine for winding up the four main guys. The front end of the

skidder carries a swinging loading boom mounted on a turntable and capable of swinging through an arc of 180 deg. On the turntable is mounted a 3-friction-drum engine for loading; one of the drums lifts and lowers the logs, the other two swing the boom to the right or left. Twenty-five-ton logs may be hoisted and loaded on railroad cars with this boom loader.

The rear end of the platform generally carries a water tank, as shown in Fig. 7, and in some instances an oil-fuel tank. The main cable reaches out usually 1200 to 2500 ft. radially from the spar as a center. In some instances 3000-ft. spans have been employed. On the opposite side of the spar head are the backstays, arranged to form a "walking split anchorage." It will be noted in Figs. 6 and 7 that the inner end of the main cable, as well as the backstays, are connected through blocks and falls to a swiveling band surrounding the head of the spar. The spar itself is sustained by guys operated by power drums.

When the area within reach of the cable is cleared, the cable is dropped and a duplicate cable on another radial line is tautened. The blocks and falls connecting the spar to the cable and backstays are slackened off and the cable comes to the ground and is then detached. One block and fall is then shifted to pick up a duplicate cable that had been previously laid down during the operation of logging. This new cable is then tautened and the operation goes on with slight delay. The walking split anchorages have double guys, each of a strength equal to that of the main cable. The entire cable stress may come upon either guy, allowing the remaining guy to be carried forward and secured to a stump or tree. Frequently the cable stress is sustained equally between the two back guys.

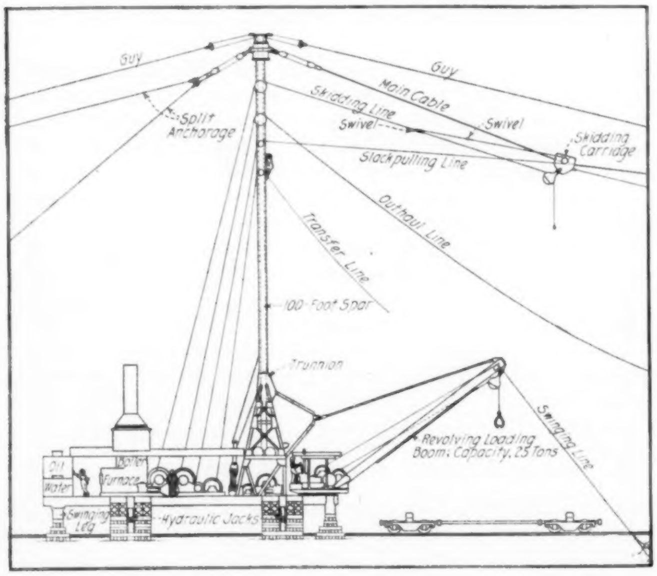

Fig. 6 Portable-Spar Cableway Skidder in Operating Position Straddling Track

Importance of the Swiveling Trunnion. From the foregoing it is evident that the spar is subject to stresses of varying intensity, coming from different directions. The spar by virtue of the universal trunnion adjusts itself in positions such that it subjects the supporting tower to downward thrusts only, all twisting stresses on tower and platform being practically eliminated.

Referring to Fig. 9, four guying lines that hold the spar upright are carried from the guy-line engine through the center of the spar, bending outward over steel pulleys mounted at the head of the spar, and leading off in four different directions to their respective anchorages. As it is scarcely possible to find four stumps suitable for anchoring these guys at equal distances from the spar head, each guy is and must be tautened by a drum independently operated. During the process of raising it is imperative that the spar shall be free to move in all directions, and this is made possible by the universal trunnion.

Operating. A crew of 16 to 18 men is required for operating a portable-spar skidder. The skidder hauls the logs along the cable and delivers them near the track, where they are picked up and loaded on cars by the swinging-boom loader. If no empty cars are on hand, the logs accumulate in a pile near the track. Good management provides empty cars with regularity. A train of empty cars is pushed by the locomotive under the platform, leaving the last car under the loading boom. The locomotive then leaves for other duty. The train of cars as loaded is pulled by a rope hauled by a "spotting drum" one car length at a time. When all cars are loaded, the train is hauled away by a locomotive, and another train of empties pushed under the skidder platform. A common complaint is "waiting for empties," but because the swinging-boom loader can load much faster than the cableway can haul, there is no material loss of output unless the delay for empties becomes serious.

Moving. When the area covered by the skidder has been completely logged, a special moving car is pushed under the skidder platform, hydraulic jacks lift the platform until the blocking is removed, and then the platform is lowered to suitable supporting sockets on the car. The spar is then lowered to the position shown in Figs. 10 and 11. All blocks and rigging are left secured to the spar, its upper end resting on a second car in front of the moving car. In this position, because of its trunnion connection, the whole skidder can be transported around curves to its next setting.

Raising the Spar. After the machine has been jacked up at its new setting, the spar is raised by power through a block and fall attached to the tail of the spar. The spar guys are manipulated at the same time to steady the head of the spar when raising. The four guys, when properly adjusted, securely hold the spar in an operable position, as each guy carries approximately the same stress. The main cable and backstays are then tautened, the operating lines rigged, and logging begins. About two hours is required for moving the lighter type, and six hours for the heavier machines. Logs are hauled in at a speed of 750 ft. per min. and the empty carriage hauled back into the woods at 2100 ft. per min.

Wire-Rope Equipment for Portable-Spar Skidder. It requires about six miles of wire rope to equip any type of overhead-cableway skidder reaching out 2000 ft. Every cable, rope, and guy should be of high-grade material because portability is a prime requisite; hence the greatest strength for a given weight is essential for safety and economy in operation.

Two main cables are required, each of which is $1^3/_4$ in. in diameter (6×19) with a wire center, having an ultimate strength of about 120 tons and weighing $5^1/_3$ lb. per ft. There is a difference of opinion respecting the construction of wire rope to give the greatest service. The longer one is associated with wire rope under service conditions, the more difficult it is to express an authoritative opinion. The majority of main cables in cableway skidders employ the 6×19 construction.

The walking split anchor cables have the same strength and construction as the main cable. Other ropes, most of which have wire centers and are all of high-grade material, 6×19 construction, are as follows:

	Diameter in inches
Tower guys	$1^3/_8$
Tower-purchase guys	$1^1/_8$
Skidding and receding lines	$1^1/_8$
Transfer and heel-block lines	$^3/_4$
Car-spotting line	1
Loading line	1
Boom-swinging lines (hemp center)	$^3/_4$
Tower-raising lines	$^3/_4$
Slackpulling lines	$^9/_{16}$
Straw line	$^1/_2$
Tail-tree guys	$^7/_8$ and 1
Choker wires	1

Blocks and Rigging. For the skidding and receding ropes, $1^1/_8$ in. in diameter, 30-in.-diameter pulley blocks with roller bearings are recommended for the head spar. The load carriage usually carries a Lidgerwood Auto-Lub 24-in. block. For the transfer lines, $^3/_4$ in. in diameter, and the slackpulling line, $^9/_{16}$ in. in diameter, 18-in.-diameter blocks are used; and for the straw line, $^1/_2$ in. in diameter, Auto-Lub 12-in. blocks. All of the above blocks are secured to the head spar.

The tail-tree blocks must be manhandled, and the weight of the

blocks should be kept low. It is therefore customary to use 18-in. to 22-in. roller-bearing blocks at the tail tree. In permanent cableways with fixed towers, sheaves of 40 in. diameter for $^3/_4$-in. rope are common.

We have ample testimony that the life of wire rope will be greatly increased by a relatively slight increase in the diameter of the sheave. Daniel Adamson, in 1912, addressing the Institute of Mechanical Engineers of Great Britain, said: "Speaking generally, Mr. Biggart's experiments show that increasing the diameter of the pulley by an amount equal to two circumferences of the rope, will double the life of the rope." This rule takes no account of abrasion of the rope caused by passing over gritty ground.

Suppose we apply Biggart's law to a 24-in. block carrying $1^1/_8$-in. rope. The circumference of $1^1/_8$-in. rope is $3^1/_2$ in., which multiplied by 2 equals 7 in., and 7 in. plus 24 in. equals 31 in. Thus, if

FIG. 7 VIEW OF SKIDDER POWER PLANT SHOWING WATER TANK

the sheaves were increased in diameter from 24 in. to 31 in., the life of the rope would thereby be doubled were there no abrasion of the rope elsewhere. Other experiments by Mr. Biggart showed that internal lubrication of wire ropes practically doubled their life.

Bending of wire rope over small sheaves is more serious than generally known. Bulletin No. 229 of the Bureau of Standards, Washington, is a record of tests of wire rope when bent over sheaves, and seems to show that the ordinary 6 × 19 wire rope bent over a pulley of 10 diameters will break at a strain 21 per cent less than the same rope when tested without a bend. For ground hauling many of the blocks must be light because they have to be carried by men about the woods. It is common practice to bend $1^1/_2$-in. 6 × 19 wire rope around sheaves in blocks of only 12 in. diameter. If a $1^1/_2$-in. rope suffers 21 per cent loss in strength about a sheave of 10 diameters, which would be 15 in., it certainly will suffer a reduction of 25 per cent in strength bending about a 12-in. sheave, only 8 diameters.

Wire-rope makers have given earnest consideration to the needs of the logger, realizing the necessity in many instances for employing blocks with sheaves of absurdly small diameters. They have produced new types of wire ropes that have shown marvelous results. But whatever their flexibility, strength, or ductility of wires, the stresses are the same.

Cable Stresses. The main cable, $1^3/_4$ in. in diameter, with an ultimate strength of about 240,000 lb., must at times support a load in its center of 40,000 lb. (20 tons), this being the average pulling power given to the skidding line by the skidding engine. The cable stress depends, of course, upon its sag or deflection.

The following formula for main cable stresses has long been used and found reliable:

$$\text{Stress in main cable} = \frac{WS^2 + 2\,PS}{8D}$$

where W = weight of cable per foot, pounds
S = span of cable in feet
P = total load at center, including weight of carriage, in pounds
D = deflection at mid-span in feet, under load.

In this example $W = 5.33$, $S = 2000$ ft., $P = 40{,}000$ lb., and

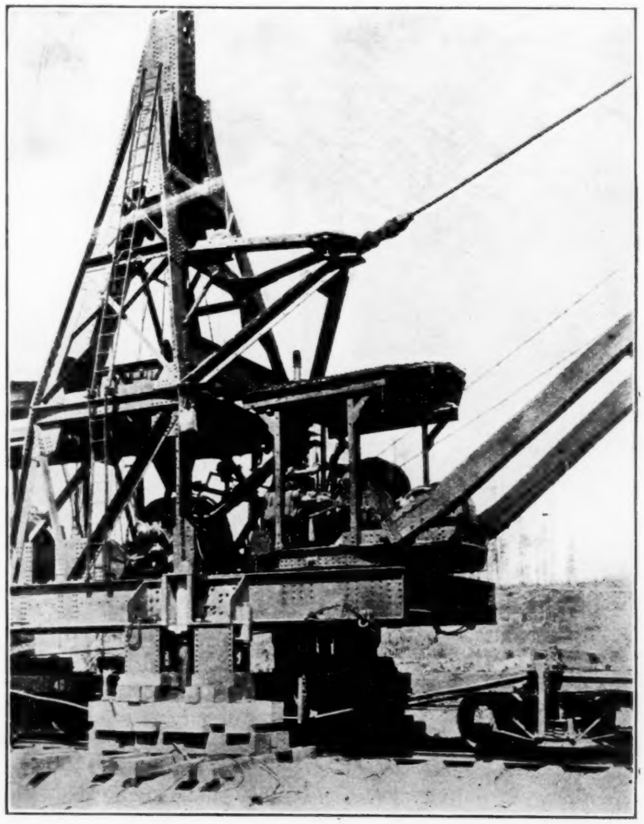

FIG. 8 PARTIAL VIEW OF SKIDDER SHOWING TOWER, SWIVELING TRUNNION, AND LOADING ENGINE

$D = 100$ ft. Assuming a cable stretched horizontally carrying a load of 20 tons at the center, we obtain the following stresses in the main cable, calculated according to the above formula and the values given for W, S, P, and D.

With a deflection loaded of 5 per cent, or 100 ft., cable stress is 226,000 lb.
With a deflection loaded of 6 per cent, or 120 ft., cable stress is 189,000 lb.
With a deflection loaded of 7 per cent, or 140 ft., cable stress is 162,000 lb.
With a deflection loaded of 8 per cent, or 160 ft., cable stress is 142,000 lb.
With a deflection loaded of 9 per cent, or 180 ft., cable stress is 126,000 lb.
With a deflection loaded of 10 per cent, or 200 ft., cable stress is 113,000 lb.

Elasticity of Cableway Skidder. The sag of the main cable unloaded must never be less than 5 per cent, and experience has shown that the main cable, if in good condition, is safe if that rule is followed. The stress of a 2000-ft. span cable unloaded is about 27,000 lb. The safety of the main cable is traceable to the inherent elasticity of the system as a whole. No tree can be guyed to prevent its yielding to overstresses. The main cable itself, the guys that support the spars, are elastic. Even the stumps employed for anchorages yield. All these elements yield automatically as the stress is applied. A 2000-ft. cable sagging 200 ft. (10 per cent) under a heavy load is only 40 ft. longer than the same span of cable sagging 100 ft., or 5 per cent. A 6 × 19

cable should elongate 2 per cent within its elastic limit, and 2 per cent of 2000 ft. is 40 ft. The unloaded cable with 100 ft. deflection with stress of 27,000 lb. may have stretched, say, 8 ft., and could therefore stretch 32 ft. more under a load approaching the elastic limit. The yield of the guys, the trees, and the stumps doubtless aggregates another 8 ft. This explains the safety of the main cable. The main cable rarely has clearance sufficient to sag 200 ft.; hence the log is not off the ground. When carrying logs over a deep ravine or valley the cable is likely to sag down nearly 180 ft., stressed to 126,000 lb. and yielding a factor of safety of 2. If the cable is stretched so tight that the sag with a 20-ton load is only 5 per cent, the cable is in danger of rupture. At all events a strain of 226,000 lb. might exist, which would exceed the elastic limit, and when so stressed the cable loses its elasticity and is likely to rupture at any moment.

The skidding line, $1^1/_8$ in. in diameter with an ultimate strength of 110,000 lb., has an apparent factor of safety exceeding $2^1/_2$ when pulling 20 tons. But the skidding line bends over two

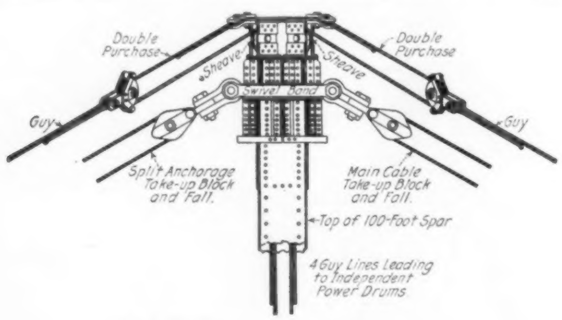

FIG. 9 DETAIL OF SPAR HEAD

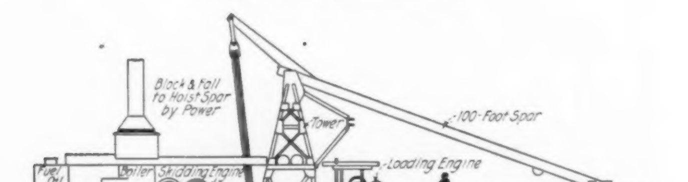

FIG. 10 SKIDDER IN MOVING POSITION WITH SPAR LOWERED

pulleys and its ultimate strength may thus be reduced, which would reduce the factor of safety.

Another contributing element to safety of the main cable resides in the choker, 1 in. in diameter; and the choker, from the fact that it is a choker, must take a sharp bend around a hook whose curvature is usually much less than 10 diameters, and therefore its ultimate strength would be reduced by about one-third. The 1-in. choker at the point of the bend has a factor of safety of much less than 2 and will break before the skidding line or main cable. In fact, these chokers rarely break unless the load comes on them suddenly, and this is doubtless due to the fact that the entire load is rarely carried free above the ground.

Possible Improvements. Many of the facts given in the foregoing paragraphs form topics for discussion at the annual meetings of the loggers' congresses.

Failure of main cables are usually traceable to insufficient sag, and the difficulty of determining the amount of sag or deflection in logging operations has given rise to the suggestion of building a tension-governed cable reel to automatically pay out when overstresses come upon the main cable and to wind in the cable after the stress has been relieved. The Merrill-Ring Logging Company have an automatic tension towing engine on their tug *Wanderer* which is employed in towing rafts of logs. This towing engine automatically pays out under overstresses and winds in when the hawser slackens, and was pointed out at one of the loggers' conventions as having just the feature that would satisfy the demands for safety to the main cable which have been noted. This automatic tension towing engine has 13-in. by 13-in. cylinders and is rated at 20,000 lb. It uses a $1^1/_8$-in. hawser. It is easy to be seen that when an automatic cable-reel engine is produced for $1^3/_4$-in. main cable, it must have a rating five times as great. This could be done.

Management. Successful logging depends largely on management. The successful manager selects the best machine for the problem in hand. One fundamental advantage of the overhead cableway is that one end of every log is lifted and the logs hauled in clear of all obstructions. Because of this method the length of the haul may be three times that of any ground-haulage yarding system. What is known locally as the "high-lead yarder" accomplishes the same thing for short hauls. In the high-lead yarding method the main hauling line is led over a pulley block attached to the spar tree, frequently 200 ft. above the track. While the overhead skidder is doubtless the cheapest in a majority of instances of mountain logging, nevertheless heavy stands of timber within 600 ft. of the railroad can be hauled and loaded more rapidly with a yarder leading the hauling line 200 ft. above the track. But it is equally true that for hauls of 100 ft. from the track, a locomotive crane will be cheaper than the yarder. If the logs be piled along the track the cost with a crane will be the cheapest. This explains the presence in our largest operations of several types of logging equipment.

For example, confidential reports for a year's operation in an enterprise employing about a dozen logging machines of various types show labor costs (only) as follows:

Locomotive cranes—dragging and loading near tracks	\$0.83 per M.
Donkeys—ground hauling	2.19 per M.
Two-speed high-lead yarders	1.95 per M.
Portable-spar cableway skidder	1.86 per M.

The economy of the locomotive crane for short hauls, perhaps 100 ft., is demonstrated.

The high cost recorded for donkey logging is doubtless due to hauling at too great a distance.

The moderate cost for the two-speed high-lead yarders is probably due to the advantages arising from the two-speed feature

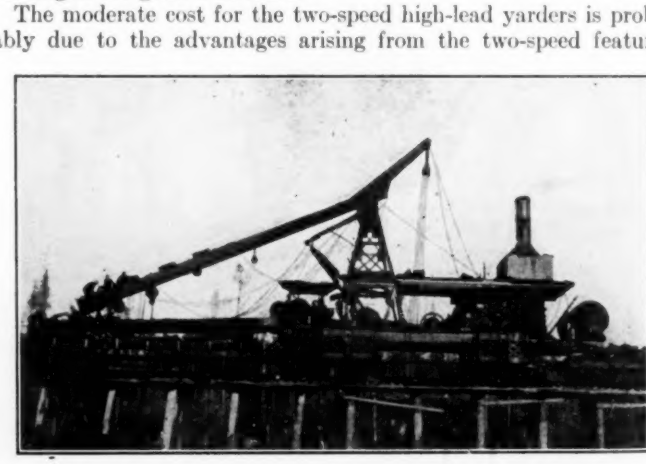

FIG. 11 VIEW OF SKIDDER WITH SPAR LOWERED FOR MOVING

and also to good management in limiting the haul to within 600 ft. and the selection of good stands of timber.

The low labor cost of logging by the portable-spar skidder is natural. Were it not for the great economies effected through its use, no such wide sale of these most costly of all logging machines would have been made.

The relative merit of various methods of logging is a frequent topic of discussion at annual logging congresses. One successful manager having personal contact with the different types, said: "I believe a skidder (overhead skidder) compared with donkey engines (ordinary surface hauling machines) and considering hauls beyond 1200 ft., will log anywhere from \$1 to \$2 a thousand cheaper."

A close student of logging costs said: "The cost of loading logs on cars by the skidder is 64 per cent of the cost incurred with donkey engines, which includes, in addition to actual labor, the cost of the cable, general expense and repairs, and a depreciation charge of 10 per cent. There is also a saving in labor for the reason that practically no landings are required and little swamping is neces-

sary. The logs are not sniped [i.e., end of the log beveled off so that it will offer less resistance in hauling]. The fact that only one end of the log is dragged on the ground means that the logs go to the mill with far less grit in them, and that means a saving in the expense of sharpening saws."

To management again we must credit the savings that are indicated above, for, as we shall see later, the labor items in well-regulated logging operations represent 50 per cent of the total cost of logging.

Operation of Lidgerwood Portable-Spar Skidders

Not until some standardized method of cost accounting for logging operations is generally adopted will it be possible to make any complete comparisons in methods or machines. Engineers naturally desire to know how the cost of any operation is subdivided, and Table 1 has been prepared from confidential data supplied by a corporation employing several portable-spar skidders. Their logging camp is well managed, and ground conditions are favorable for low costs.

TABLE 1 AVERAGE PERCENTAGES OF COST OF LOGGING WITH PORTABLE-SPAR SKIDDERS WHILE HANDLING AN AVERAGE OF 11,000,000 FT. LOG SCALE PER SKIDDER

Item		Per cent
1	Skidding, ground labor	25.5
2	Loading, ground labor	10.7
3	Enginemen	6.3
4	Foremen	4.4
5	Watching	2.2
6	Fuel	5.05
7	Water	3.15
8	Moving	1.57
9	Repairs and renewals to machinery	6.9
10	Wire-rope renewals	3.15
11	Oil and waste	0.47
12	Tools and supplies	0.71
13	Railroad and transportation (estimated)	25.2
14	Depreciation on logging machines	4.7
	Total	100.00

Labor Items. The first five items in Table 1 are for labor and total 49.1 per cent. Labor is necessarily an extremely variable item, greatly affected by ground conditions, morale, and management. This item of nearly 50 per cent is an invitation to invent new appliances to reduce the number of men employed. It is evident, however, that the cost of such appliances must not be excessive. With the overhead-cableway method of logging, a number of logs can be hauled in at each trip; neither stumps, rocks, nor fallen trees retard their journey, because every log is lifted above obstructions. On the return trip to the woods a number of chokers are taken out and distributed along the trail. These chokers are secured to the logs wherever they lie and are coupled up by a short piece of skidding line threaded through the hooks connecting each choker. When the skidding line is lowered to the ground it is quickly attached to the short piece of rope mentioned. The skidding line when wound in draws the logs together and forms a load. By this means a single cableway skidder serves several squads of men and necessarily results in keeping the skidder continually busy hauling logs. Much study has been given to this problem of gathering logs, but doubtless there is room for improvement. Another labor-saving feature of the overhead method as compared with the ground method resides in the fact that a 1-in. choker, which is easy to handle, will carry the largest log, whereas a $1^3/_8$-in. choker, much heavier to handle, would be required for the same log in the ground-haul system. The $1^3/_8$-in. choker is generally regarded as the maximum practical size, but its great weight and stiffness make it difficult to handle in the woods.

Item 6—Fuel, 5.05 Per Cent. This item shows the cost of wood fuel, and while it is small, it might be further reduced. The low cost recorded is the natural result of a well-designed boiler with the crown sheet unusually high, the furnace unusually large—which means that the fuel is consumed in the furnace. The tubes, $2^1/_2$ in. in diameter, do not soot up as quickly and are spaced properly to promote rapid water circulation. The only additional fuel-saving appliance in this example was the insulating material covering the boiler and pipes. Superheat was not employed, nor were feedwater heaters. Where oil has been substituted for wood marked savings have been shown, because wood fuel must be sawed, split, and handled by labor, and wages are high. Aside from this, men insist on sawing up good logs because they are easier to split. Thus we find fuel cost to a considerable extent is a matter of management.

In one camp the use of oil saved the wages of two men to saw and split wood, and an extra fireman to handle it. The good timber was not wasted for fuel. The saving in this instance amounted to fully 35 per cent. It is easier to regulate and maintain a uniform boiler pressure with oil than with wood. Further savings with oil fuel of perhaps 9 per cent should be effected if the brick arch, as employed in railroad locomotives, were introduced. Another economy may be effected by control of the air supply, a matter more important than usually considered. The average lumberman seems to be satisfied if the fireman maintains full boiler pressure throughout the day, because he knows that constant power is essential in order to avoid delays to the entire crew; delays reduce output, and this immediately increases the cost per thousand.

Comparison of Boilers. A comparison of fuel costs between two cableway skidders in which the difference between the ma-

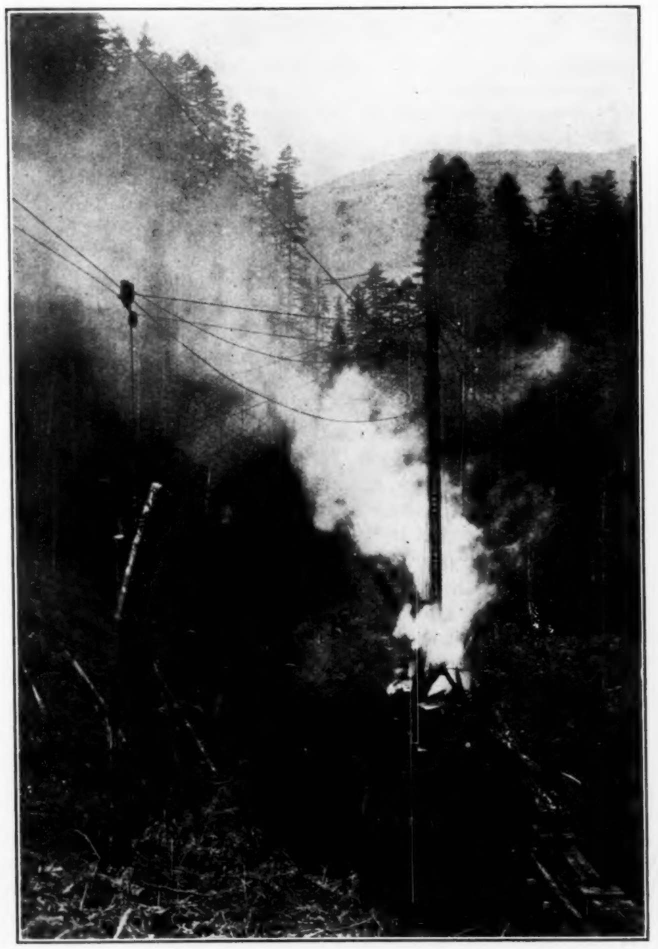

FIG. 12 PORTABLE-SPAR SKIDDER IN THE TALL TIMBER

chines resided chiefly in the design of the boiler, showed a fuel cost per thousand feet of 12 cents on one and on the other $33^1/_3$ per cent more, namely, 16 cents; all other conditions were approximately alike.

Importance of Fuel Saving. A practical operator finding his fuel costs as low as 5 per cent (only one-tenth of his labor costs) is very apt to turn a deaf ear to any one who may propose to add complicated mechanisms for fuel saving. His answer is likely to be that the instant he adds complications to his boiler to save fuel, he will have to pay higher wages to superior men to maintain such appliances in operating condition. One operator's plea in favor of electric logging was that it produced "constant power," and constant power is vital to maintain a low cost for logging. But many are unable to make the large investment required for electric logging for the sake of "constant power," especially as "constant power" is easily obtained with steam boilers using oil fuel. The boiler

must be large enough, with a properly designed furnace and ample water circulation. Such boiler should be built for 50 lb. more pressure than demanded by the engines for adequate operation; then by introducing a pressure-reducing valve between the boiler and the throttle, a reservoir of steam pressure is provided. The engine operator then obtains a constant power, even though the pressure in the boiler varies from that required by the engine to a maximum of 50 lb. higher. The advent of electric logging will naturally stimulate an interest in more economical steam logging, and there are many economies that have been found practicable in locomotive service that may be adopted. This stimulating influence must be credited to our electrical friends. This has actually occurred in the improvements in steam locomotives to keep pace with the economies in the electric locomotives.

Locomotive Data. Julius Kruttschnitt, chairman of the Board of the Southern Pacific Railroad System, gives many valuable data on fuel-saving appliances which have been put into practical use on Southern Pacific locomotives. He credits them with the following net savings in fuel:

	Per cent
Brick arch	9
Feedwater heating	6
Superheat (to a moderate degree)	17.4

Feedwater purifiers are praised by Mr. Kruttschnitt, and it is quite possible that the Filtrator, which is merely a container for linseed through which live steam passes in circulation back to the boiler and which prevents the formation of scale, may yet be found on boilers employed in logging operations.

Water Cost. There is a wide range of estimated water costs per thousand feet of logging scale. This cost has been studied for several operations. The maximum cost has been given in one instance at 80 cents per 1000 ft. The minimum recorded cost is one-third cent per 1000 ft. The average probably is in the neighborhood of 10 cents.

Item 9—Repairs and Renewals to Machinery, 6.9 Per Cent. This is a relatively small item, although larger than that for fuel, and reflects great credit on the management in selecting a machine with sufficient reserve strength, with bearings of large dimensions, with shafts so large that they do not bend under the influence of a pull and bind in the bearing, destroying the babbitt, in maintaining a stock of spares that fit where they belong, and in care of the machinery, especially in the selection of proper lubrication materials and maintaining thorough lubrication.

Item 10—Wire-Rope Renewals, 3.15 Per Cent. This item will surprise a great many operators, because it is generally supposed that because the overhead cableway involves more wire rope than ground-logging methods—that the cost of renewals should be greater, not less. One student who has given a great amount of study to the ground-hauling methods found that wire-rope renewals cost 16 per cent.

Item 11—Oil and Waste, 0.47 Per Cent. This perhaps is lower than it should be, and it is probable that in the future there will be a general recognition that both fuel and renewal costs may be greatly reduced through a slight increase in the cost of lubrication. There are many splendid examples of improved lubricating methods in our better grades of automobiles.

Item 12—Tools and Supplies, 0.71 Per Cent. This item is relatively insignificant.

Item 13—Railroad and Transportation, 25.2 Per Cent. (Estimated.) No fair comparison in the cost of logging as between the overhead cableway and the ground-hauling methods can be made unless the cost of both operations includes the cost of railroad and transportation. Much of the standing timber today in the great Northwest is in mountainous regions, where the cost of railroad building is extremely high. Whatever may be the cost of railroad building with the ground-logging methods, it is inevitable that the cost with the cableway method, hauling at double the distance, will be reduced at least 50 per cent. High-lead ground-hauling methods are usually limited for economical operation to 800 ft. and the cableway method to perhaps 2000 ft. It is a fact, however, that surface logging is carried on at 1300 ft., and cableway logging up to 3000 ft. The cheapest logging by cableway, however, generally speaking, resides at a point nearer 2400 ft. than 3000 ft. Where 3000-ft. cableways are used, the ground conditions are so extremely unfavorable that even though the cost may seem high, it is doubtless cheaper than by any other method.

The Diesel Engine. The Diesel engine yields the greatest amount of power per unit of fuel, especially in small units. It requires water for cooling only and much less than a steam boiler. An economical and practicable method of transmitting the power of Diesel engines to the drums of a logging engine is yet to be determined, but if experience on shipboard is any criterion, we may soon witness portable Diesel-electric generating plants delivering current to d.c. electric motors driving the drums through gearing. If the story of the development of the locomotive is any criterion, and it should be, it is confidently predicted that for many years to come the steam engine will be the favored motor. In fact, the advent of the Diesel engine and electric motor will necessarily stimulate the adoption of fuel-saving appliances for the steam engine that promise to reduce the fuel cost materially.

Samuel Vauclain, president of the Baldwin Locomotive Co., recently stated that his company was building a Diesel-propelled locomotive which he recommended for long hauls where water was scarce, but he added that its cost would be more than twice that of a steam locomotive of equal power.

Diesel engines of today are extremely heavy and may weigh more than an equivalent steam engine with its boiler filled with water. Gasoline engines have the advantage in weight and may weigh less than one-tenth of an equivalent Diesel engine.

Pulpwood and Forest Conservation

It has been said that the loggers of Washington and Oregon leave enough waste wood on the ground to supply ten paper mills with pulpwood. To recover this waste wood and transport it to the paper mills at a cost which will command the market is a real problem.

The Crown Willamette Paper Co., near Astoria, Ore., has found the portable-spar cableway skidder an efficient apparatus to reach out from existing logging railroads, pick up this waste, and load it on railroad cars for shipment. One of these skidders, with a crew of 17 men, is salvaging about 500,000 ft. per month, and is in a fair way of solving the problem of cost. The man of vision, with thoughts for the future, clearly sees that such a practice of relogging must reduce the fire hazard, must promote regrowth, and incidentally save other partly grown forests from being cut down to satisfy the demand for newsprint.

It is difficult to imagine where the chambers of commerce of Oregon and Washington could find a more worthy cause to foster than this one of salvaging pulpwood, not only for the profit and happiness of future generations through this conservation of forests, but because the present generation residing in Washington and Oregon will profit through the establishment of more paper mills within their borders. Paper-mill machinery would then naturally be made on the Pacific Coast, thus adding further industries.

How the Automobile Helps the Railroads

REFERENCE has frequently been made to the fact that the business created for the railroads by the automotive industry offsets that taken away by automobiles and buses. In 1924, 726,000 carloads of finished automobiles and parts were shipped by rail. In addition there were 50,000 carloads of tires and 640,000 tank carloads of gasoline for automobile use. The coal, steel and other raw materials used in the manufacture of automobiles also added a great many tens of thousands of carloads for which separate figures are not available. Inasmuch as the automobile is wholly responsible for the activity in high-grade road building, the 550,000 carloads of cement, much of which went into roads and highway bridges should also be considered as a direct result of the automobile industry. The National Automobile Chamber of Commerce estimates that if complete data were available, approximately 2,000,000 carload shipments should be credited to the automobile industry. An appreciation of what these figures mean can best be had from a comparison with other commodities. In 1923 the wheat crop, which has always been considered a barometer of railroad prosperity, required 572,000 carloads, and the corn crop, 400,000 carloads. (*Machinery*, May, 1925, p. 714.)

Specific Heat-Specific Gravity-Temperature Relations of Petroleum Oils

A Comprehensive Study of Available Data, Showing the Influence of the Specific Gravity upon the Value of the Specific Heat at Different Temperatures—Charts for the Use of Petroleum Engineers in Designing Equipment

By WILLIAM RANKINE ECKART,[1] STANFORD UNIVERSITY, CAL.

ADVANCEMENT in the design of apparatus for the petroleum industry has been greatly handicapped due to the lack of full and reliable data on the physical properties of the fluids dealt with, together with their variation under the different conditions of pressure and temperature at which they must be handled.

Until such data become available the designing engineer will be forced to rely upon such meager information as he now possesses and to cautiously exercise his judgment in its application to the purpose at hand.

When one considers the complex nature of petroleum, the great variation in its composition from different fields, and the many products which are derived from the crude from any particular source, he is not surprised at the meagerness of the information, but is forced to realize the magnitude of the task of obtaining sufficient or accurate data which might be applicable to the problems with which he is confronted.

In addition the difficulty and time required for making the different determinations are a serious handicap. Most of them require apparatus and methods of extreme precision and should only be attempted by trained observers, skilled in the handling of the apparatus and with full knowledge of its limitations and possible errors.

Within recent years the necessity for these data has forced many a worker in the petroleum industry to gather together the available material from all possible sources, to supplement it, whenever possible, with additional data obtained experimentally, and to study, analyze, and coördinate the results so as to make them serve his purpose. Much of this material has been published and made more accessible, so that at present it is in much better form for use.

It is the purpose of this paper to deal primarily with one physical property of petroleum oils, namely, the specific heat, which so far has not been treated as fully or with as satisfactory results as have some of the others; and to show the influence of the specific gravity upon the value of the specific heat at different temperatures.

The value of the specific heat commonly used in practice for liquid hydrocarbons is 0.50. As values as low as 0.40 and as high as 0.60 have been determined, an error may be involved within these limits as great as ±20 per cent. Any relationship, empirical or otherwise, which may be established so as to make it possible to confine this error within narrower limits should be of estimable value.

Scope of Data Used

The material used for the preparation of the charts presented in this paper has been gathered from all available sources. It is of a truly representative character and is not limited in any sense to the work of any single investigator, to any particular method, or to samples from any one field.

Altogether it represents 142 determinations made by eight different authorities and covers the following fields: Pennsylvania, Oklahoma, Texas, Louisiana, Wyoming, California, Mexico, Japan, Russia, Roumania, Burma, and others unknown. (See Table 1.) It covers pure hydrocarbons of the paraffin series; C_nH_{2n+2}, the methylene series, C_nH_{2n}; crude oils and commercial petroleum distillates. The specific gravities of the oils range from 0.963 to 0.664 at 60 deg. fahr., and the temperatures of the determinations of specific heat from 52 deg. fahr. to 190 deg. fahr.

Likewise, due to the fact that these investigators used widely different methods, temperature ranges, etc. the data are subject to discrepancies due to instrumental, personal, and other errors. Owing to the impossibility of accurately judging these matters, all points have been included and give equal weight, making the results impartial from that standpoint.

Preliminary Studies

The preliminary study upon which this paper is based was made in March, 1919, and was due to the impression gained of a consistent relationship between the specific heat and specific gravity for a number of crude oils, the data for which were determined by Mabery and Goldstein.[2] A reading of the original publication showed that this view was not wholly shared by the investigators, who stated:

> These values show that the specific heat of the crude oils is an important property from a practical point of view. It also appears that there is *no close agreement between specific heat and specific gravity*. Pennsylvania oil stands at the head and Berea grit, with a much larger proportion of volatile constituents, is next. Of the heavier oils, it appears in general that the specific heats are much lower, but with no definite relation.

Referring to the data on specific heat, they further stated:

> In general, the data on specific heats of organic compounds are meager and not concordant. For the same substance the results of different observers seldom agree in the third decimal place; they often do not agree in the second, or even in the first place. (See tables of Landolt and Börnstein.) These variations are probably due to the fact that specific heat is materially affected by the impurities in the substance and the temperatures at which it is taken. Then, furthermore, from the details of the determinations of the hydrocarbons described in this paper, it was found that impurities depressed the specific heats very considerably.

An examination of some of the original papers, from which the data published by Landolt and Börnstein were taken, disclosed the fact that one of the reasons for some of the discordant results was that of apparent typographical errors in the original publications, especially where the figures were wrong in the first and second decimal places.

Mabery and Goldstein did find for the paraffin and also for the methylene series that:

> There is a uniform decrease in specific heat with molecular weight. Furthermore, the normal hydrocarbons, such as heptane, C_7H_{16} [boiling point (b. p.) 98 deg. cent.], and decane, $C_{10}H_{22}$ (b. p. 172 deg. cent.) have higher specific heats than their isomers, such as isoheptane, C_7H_{16} (b. p. 91 deg. cent.) and isodecane, $C_{10}H_{22}$ (b. p. 162 deg. cent.).

In December, 1920, Bushong and Knight[3] published considerable additional data based upon their own experiments covering petroleum and its products from a number of fields and with determinations made upon the same product at a number of different temperatures. With these determinations of specific heats they also gave the density of the oil in each case, which data have unfortunately not always been included by other authorities with their determinations of the specific heats.

This led to a further study by the author of the present paper and to the production of a chart, in January, 1921, almost identical with Fig. 2, covering the range of the available experimental data. This chart has for four years been used in practice with satisfactory results.

Present Studies

In the studies covered by this paper the work previously done

[1] Professor of Mechanical Engineering, Stanford University, Mem. A.S.M.E.

Contributed by the Petroleum Division and presented at a meeting of the Los Angeles Local Section of The American Society of Mechanical Engineers, Los Angeles, Cal., December 22, 1924, and at a meeting of the Mid-Continent Local Section, Tulsa, Okla., April 24, 1925.

[2] Mabery and Goldstein, On the Specific Heats and Heat of Vaporization of the Paraffin and Methylene Hydrocarbons. *Am. Chem. Jl.*, vol. 28 (1902), p. 66.

[3] Bushong and Knight, The Specific Heat of Petroleum at Different Temperatures. *Jl. Indus. & Eng. Chem.*, vol. 12, no. 12 (Dec., 1920), p. 1197.

TABLE 1 DATA ON THE SPECIFIC GRAVITY AND SPECIFIC HEAT OF PETROLEUM OILS

(AUTHORITIES; B. & S., Bartoli & Stracciati; B. & K., Bushong & Knight; K., Kissling; L., Longuinine; M. & G., Mabery & Goldstein; V. R., Von Reis.)

	Authority	Sp. gr. at 60 deg. fahr.	Observed temperature range, deg. cent.	Mean temp., deg. fahr.	Sp. gr. at mean temp.	Sp. heat at mean temp.	Sp. heat at 60 deg. fahr.
Normal Paraffin Hydrocarbons							
Hexane	M. & G.	0.6645	0–50	77	0.656	0.5272	0.5105
	B. & S.		16–37	79.7	0.655	0.5042	0.4859
	V. R.		16.24–52.8	94	0.648	0.5517	0.5179
	V. R.		17.3–60.9	102	0.644	0.5591	0.5174
	V. R.		18.5–70.8	112	0.639	0.5652	0.5138
	V. R.		20–68.9	112	0.639	0.5690	0.5173
	V. R.		18.2–79.5	119	0.6355	0.5615	0.5043
	V. R.		20–100	140	0.625	0.6000	0.5200
Heptane	M. & G.	0.688	0–50	77	0.680	0.504	0.4881
	M. & G.		0–50	77	0.680	0.5074	0.4913
	B. & S.		18–51	94.1	0.6715	0.4869	0.4570
Octane	B. & S.	0.705	12–19	60	0.705	0.5111	0.5111
	M. & G.		0–50	77	0.695	0.505	0.489
	L.		20–123	161	0.657	0.578	0.484
Nonane	M. & G.	0.721	0–50	77	0.713	0.503	0.4871
Decane	B. & S.	0.732	14–18	61	0.732	0.5058	0.5049
	M. & G.		0–50	77	0.724	0.5021	0.4862
	L.		21–154	189.5	0.674	0.590	0.4723
Isodecane	M. & G.	0.7515	0–50	77	...	0.4951	0.4794
	L.			190.9	...	0.5899	0.4713
Undecane	M. & G.	0.743	0–50	77	0.7355	0.501	0.4851
Dodecane	B. & S.	0.752	14–20	62.6	0.751	0.5065	0.5042
	M. & G.		0–50	77	0.7445	0.500	0.4842
Tredecane	M. & G.	0.759	0–50	77	0.7515	0.499	0.4832
Tetradecane	B. & S.	0.7662	14–21	63.5	0.765	0.4995	0.4962
	M. & G.		0–50	77	0.759	0.497	0.4812
Pentadecane	M. & G.	0.772	0–50	77	0.765	0.497	0.4812
Hexadecane	B. & S.	0.7765	15–22	65.3	0.7743	0.4964	0.4914
	M. & G.		0–50	77	0.7695	0.496	0.483
Crude Oils							
Pennsylvania	M. & G.	0.8125	0–50	77	0.806	0.5000	0.4842
Berea Grit	M. & G.	0.797	0–50	77	0.790	0.4690	0.4541
Japanese	M. & G.	0.8652	0–50	77	0.8588	0.4532	0.4388
Texas (Lucas Well)	M. & G.	0.9230	0–50	77	0.917	0.4315	0.4178
Russian	M. & G.	0.9109	0–50	77	0.905	0.4355	0.4217
Wyoming	M. & G.	0.8846	0–50	77	0.878	0.4323	0.4186
California	M. & G.	0.9628	0–50	77	0.957	0.3980	0.3854
Texas	M. & G.	0.9496	0–50	77	0.944	0.4009	0.3882
Crude-Oil Fractions							
Fraction 100–165° C. (Sp. gr., 0.7524 at 15° C.?)	K.	0.7522	15–20	63.5	0.751	0.459	0.4560
	K.		20–25	72.5	0.747	0.469	0.4580
	K.		25–30	81.5	0.743	0.475	0.4561
	K.		30–35	90.5	0.739	0.490	0.4629
	K.		35–40	99.5	0.735	0.505	0.4694
Fraction 165–170° C. (Sp. gr., 0.8045 at 15° C.?)	K.	0.8042	15–20	63.5	0.803	0.469	0.4659
	K.		20–25	72.5	0.7995	0.474	0.4629
	K.		25–30	81.5	0.7958	0.481	0.4619
	K.		30–35	90.5	0.792	0.489	0.4619
	K.		35–40	99.5	0.7885	0.501	0.4656
Fraction 170–175° C. (Sp. gr., 0.8089 at 15° C.)	K.	0.8085	15–20	63.5	0.807	0.457	0.4540
	K.		20–25	72.5	0.804	0.459	0.4483
	K.		25–30	81.5	0.8005	0.469	0.4504
	K.		30–35	90.5	0.797	0.480	0.4534
	K.		35–40	99.5	0.7935	0.488	0.4535
Fraction 235–240° C. (Sp. gr., 0.8432 at 15° C.)	K.	0.843	15–20	63.5	0.842	0.449	0.4460
	K.		20–25	72.5	0.839	0.459	0.4483
	K.		25–30	81.5	0.835	0.460	0.4417
	K.		30–35	90.5	0.832	0.463	0.4374
	K.		35–40	99.5	0.8285	0.465	0.4322
Lubricating Oils							
Schimeröle (Sp. gr., 0.869 at 19.5° C.)	K.	0.8715	15–20	63.5	0.871	0.452	0.449
	K.		20–25	72.5	0.867	0.463	0.4521
	K.		25–30	81.5	0.8637	0.471	0.4523
	K.		30–35	90.5	0.8605	0.475	0.4487
	K.		35–40	99.5	0.857	0.479	0.4452
Schimeröle (Sp. gr., 0.9095 at 20° C.)	K.	0.912	15–20	63.5	...0.550? (0.450)...		
	K.		20–25	72.5	...0.550? (0.450)...		
	K.		25–30	81.5	...0.559? (0.459)...		
	K.		30–35	90.5	...0.566? (0.466)...		
	K.		35–40	99.5	...0.571? (0.471)...		
Miscellaneous							
Roumania (Policiori)	Bell[1]	0.8288	14–20	62.6	0.828	0.4724	0.4701
Roumania (Campina)	Bell[1]	0.8691	14–20	62.6	0.8683	0.4667	0.4664
	Bell[1]	0.8545	14–20	62.6	0.8537	0.4675	0.4652
Roumania (Bustenari)	Bell[1]	0.8421	14–20	62.6	0.8413	0.4625	0.4602
Russian kerosene	Bell[2]	0.8245	12–15	56.3	0.8237	0.435	0.4382
Russian fuel oil	Bell[2]	0.9137	12–15	56.3	0.9129	0.448	0.4513
Burma fuel oil	Bell[2]	0.8967	12–15	56.3	0.8959	0.433	0.4361
Texas fuel oil	Bell[2]	0.9267	12–15	56.3	0.9259	0.436	0.4391

	Authority	Sp. gr. at 60 deg. fahr.	Observed temperature range, deg. cent.	Mean temp., deg. fahr.	Sp. gr. at mean temp.	Sp. heat at mean temp.	Sp. heat at 60 deg. fahr.
Roumanian kerosene	Bell[2]	0.8124	12–15	56.3	0.8116	0.444	0.4472
Roumanian light benzine	Bell[2]	0.7122	16	60.8	0.7114	0.484	0.4834
Roumanian heavy benzine	Bell[2]	0.7461	16	60.8	0.7452	0.4679	0.4673
Roumanian lamp oil	Bell[2]	0.8139	16	60.8	0.8131	0.4652	0.4646
Roumanian gas oil	Bell[2]	0.8639	16	60.8	0.8631	0.4619	0.4613
Roumanian light spindle oil	Bell[2]	0.9040	16	60.8	0.9032	0.4597	0.4591
Roumanian refined oil I	Bell[2]	0.9097	16	60.8	0.9089	0.4579	0.4573
Roumanian refined oil II	Bell[2]	0.9316	16	60.8	0.9308	0.4567	0.4561

[1] P. 49. [2] P. 51.

	Authority	Deg. A.P.I. at 60 deg. fahr.	Sp. gr. at 60 deg. fahr.	Observed temp., deg. fahr.	Sp. gr. at observed temp.	Sp. heat at observed temp.	Sp. heat at 60 deg. fahr.
Caddo Petroleum and Its Products							
Crude	B. & K.	40.6	0.8222	52	0.8252	0.5003	0.5082
				126	0.7948	0.5283	0.4688
Distillate I	B. & K.	67.2	0.7121	52	0.7156	0.4933	0.5010
				102	0.6921	0.5382	0.4980
				126	0.681	0.5620	0.4987
Distillate II	B. & K.	60.8	0.7358	102	0.7168	0.5217	0.4828
				126	0.7062	0.5462	0.4847
Distillate III	B. & K.	48.9	0.7844	102	0.7674	0.5083	0.4704
				126	0.759	0.5326	0.4726
Distillate IV	B. & K.	41.2	0.8193	52	0.8223	0.4688	0.4761
				102	0.8033	0.5074	0.4695
				126	0.7937	0.5228	0.4639
				176	0.772	0.5591	0.4571
Gas Oil	B. & K.	27.1	0.8922	102	0.877	0.4554	0.4214
				126	0.8685	0.5006	0.4443
				176	0.849	0.5432	0.4441
Oklahoma Petroleum and Its Products							
Crude	B. & K.	36.1	0.8443	126	0.818	0.5192	0.4607
Distillate I	B. & K.	65.1	0.7197	70	0.715	0.4982	0.4888
Distillate II	B. & K.	53.6	0.7645	89	0.7065	0.5094	0.4825
				52	0.768	0.4751	0.4825
				70	0.760	0.4772	0.4682
Distillate III	B. & K.	47.6	0.7901	126	0.735	0.5328	0.4728
				52	0.7935	0.4706	0.4780
				70	0.786	0.4704	0.4615
				126	0.762	0.5210	0.4623
Distillate IV	B. & K.	42.5	0.8132	155	0.7497	0.5503	0.4653
				52	0.8165	0.4655	0.4728
				70	0.809	0.4658	0.4570
Gas Oil	B. & K.	27.6	0.8894	126	0.7862	0.5159	0.4578
				126	0.865	0.5038	0.4471
				176	0.846	0.5338	0.4364
Gulf Coast (Texas) Petroleum Products							
Crude	B. & K.	20.8	0.9291	70	0.926	0.4406	0.4323
				102	0.9142	0.4624	0.4279
				126	0.905	0.4823	0.4280
Solar	B. & K.	27.8	0.8883	52	0.891	0.4150	0.4215
				70	0.8842	0.4253	0.4172
				102	0.8721	0.4532	0.4194
				126	0.863	0.4729	0.4196
L. L. D.	B. & K.	22.8	0.9170	52	0.920	0.4135	0.4200
				70	0.9158	0.4187	0.4108
				102	0.902	0.4465	0.4132
				126	0.8935	0.4727	0.4195
				176	0.8755	0.5207	0.4258
H. L. D.	B. & K.	18.8	0.9415	70	0.938	0.3905	0.3831
				86	0.9325	0.4358	0.4151
				91	0.931	0.4385	0.4138
				102	0.927	0.4443	0.4111
				126	0.919	0.4724	0.4192
				155	0.9085	0.4956	0.4191
Mexican Petroleum and Its Products							
Crude	B. & K.	21.0	0.9279	102	0.913	0.4667	0.4319
				126	0.904	0.4813	0.4271
Distillate I	B. & K.	60.6	0.7366	70	0.732	0.5021	0.4926
				102	0.7185	0.5197	0.4809
Distillate II	B. & K.	50.1	0.7792	126	0.707	0.5509	0.4889
				70	0.775	0.4836	0.4744
				102	0.761	0.5055	0.4678
Distillate III	B. & K.	42.4	0.8137	126	0.7503	0.5384	0.4777
				70	0.8100	0.4736	0.4646
				102	0.7965	0.4983	0.4611
Distillate IV	B. & K.	38.0	0.8348	126	0.787	0.5193	0.4608
				70	0.831	0.4715	0.4626
				102	0.8182	0.4933	0.4565
Gas Oil	B. & K.	11.9	0.9868	126	0.8088	0.5103	0.4528
				126	0.9652	0.4573	0.4058

has been revised and the empirical relationship shown has been extrapolated to temperatures up to 800 deg. fahr. This has seemed desirable, in spite of the fact that this extension of the existing data to higher temperature ranges may prove to have been without justification when experimental data are finally obtained for that region. The charts in the higher-temperature region should be used with discretion.

No positive relationship is claimed herein between the specific heat and specific gravity of petroleum oils, nor is inaccuracy imputed to data which do not agree with the average curves presented. From a practical and engineering standpoint, if not from that of the physicist, it is believed that results warrant the use of these mean data for purposes of design, where exact experimental data are not available for the particular petroleum oil being considered.

Method of Approach

The study of the problem may be conveniently divided into five steps:

1. The variation of specific gravity with temperature
2. The variation of specific heat with temperature
3. The reduction of all data pertaining to specific gravity and specific heat to a standard temperature of 60 deg. fahr., and the determination of a mean relationship between these quantities at this temperature
4. The preparation of a chart showing the mean relationship between specific gravity and specific heat for the range of the available data
5. The extrapolation of these data to temperatures as high as 800 deg. fahr. and the preparation of a chart showing the variation of both specific gravity and specific heat with temperature for this range, or as far as the critical temperature where this is lower than 800 deg. fahr.

Variation of Specific Gravity with Temperature

The variation of the specific gravity of petroleum oils with temperature has been investigated by a number of authorities, among them the Bureau of Mines and the Bureau of Standards. The latter have published their results in the form of tables.[4] In the introduction of Circular No. 57 they state:

> The expansion tables contained in this circular are based upon the results of experiments carried on at this Bureau between July, 1912, and December, 1914. During that time about 100 samples of crude and refined petroleum oils from various parts of the United States were examined and their densities determined at various temperatures.
>
> This investigation has shown that within the limits of ordinary measurements the rate of change of specific gravity with change of temperature is the same for all oils of the same specific gravity. In the calculation of the expansion tables, the average rate of expansion found for all oils of each designed specific gravity has been used.
>
> The tables contained in this circular apply to all petroleum oils, both crude and refined, produced in the United States. Each grade of oil, gasoline, illuminating oil, lubricating and fuel oil, etc. falls into its proper place in the tables by reason of its specific gravity.
>
> Although it is generally believed that California oils have a considerably higher rate of expansion than do oils of the central and eastern states, this has not been found to be the case, and the slightly higher rate is not sufficient to cause an appreciable error in the results carried only to the degree of accuracy here given.

The range of temperatures for the more extended tables, Circular No. 154, is from 0 deg. fahr. to 195 deg. fahr. and the specific gravities from 0.600 to 0.999. Within this range of temperature the variation of the specific gravity with temperature is to all intents and purposes a straight-line function.

Wilson and Bahlke[4] have shown that this linear relation does not extend to high temperatures and that, with the exception of the heavier oils, it is not safe to use it beyond 200 deg. fahr. In their paper they present a chart for the paraffin series of hydrocarbons which carries this relation up to the critical temperatures and densities, basing the extrapolation upon the theorem of corresponding states, according to which

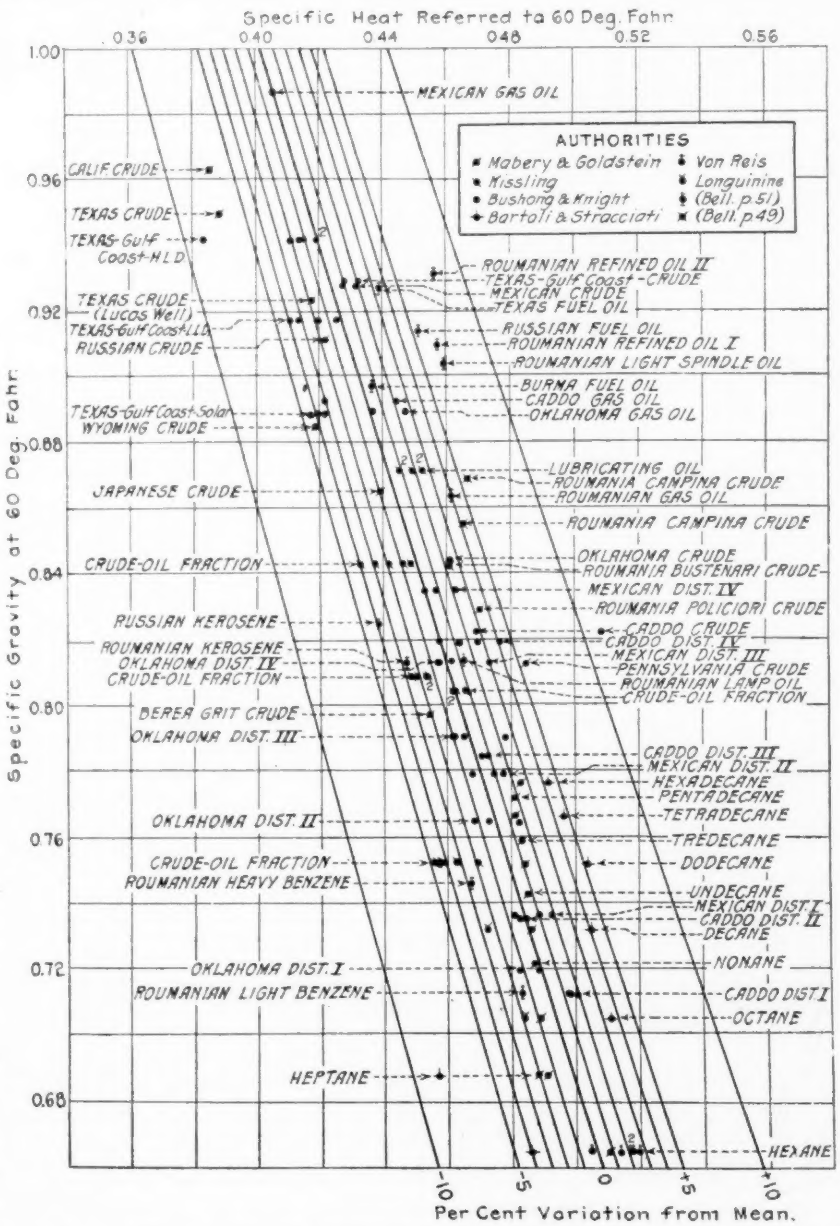

Fig. 1 Relation between Specific Gravity and Specific Heat at 60 Deg. Fahr. for Petroleum Oils

> The curve obtained by plotting the ratio of the specific volume of the liquid to the critical volume against the ratio of the temperature of the liquid to the critical temperature should be the same for all liquids.

They plotted the results for pentane, hexane, heptane, and octane, as obtained by Young, and note that

> This does not give one line for all normal paraffin hydrocarbons, but that at any one reduced temperature (T/T_c) the ratio (V_1/V_c) tends to decrease slightly with increasing molecular weight. From the values of the critical volume for the higher-molecular-weight compounds, and the measured densities of the liquid hydrocarbons at temperatures up to 200 deg. fahr., the solid lines for the higher hydrocarbons were drawn.

From these curves they calculated the actual densities and plotted them against fahrenheit temperatures. These curves

[4] Circular of the Bureau of Standards, No. 57, United States Standard Tables for Petroleum Oils. Superseded by Circular No. 154, National Standard Petroleum Oil Tables, May 29, 1924.

represent the variation of density with temperature up to 800 deg. fahr. for the paraffin series from pentane, C_5H_{12}, to eicosane, $C_{20}H_{42}$, or for a range of densities from 0.645 to 0.778.

In order to make this chart of easier application in practice, it has been redrawn as part of the final chart in this paper, Fig. 3, in which the curves are for uniform increases of specific gravity from 0.60 to 0.98. The values above 0.78 were obtained by making the assumption that as with the denser oils the linear relationship was being gradually extended to higher temperatures, it could be safely assumed that at a density of 0.98 this linear function had been established up to 800 deg. fahr. Below 200 deg. fahr. these curves agree with the values of the Bureau of Standards tables.

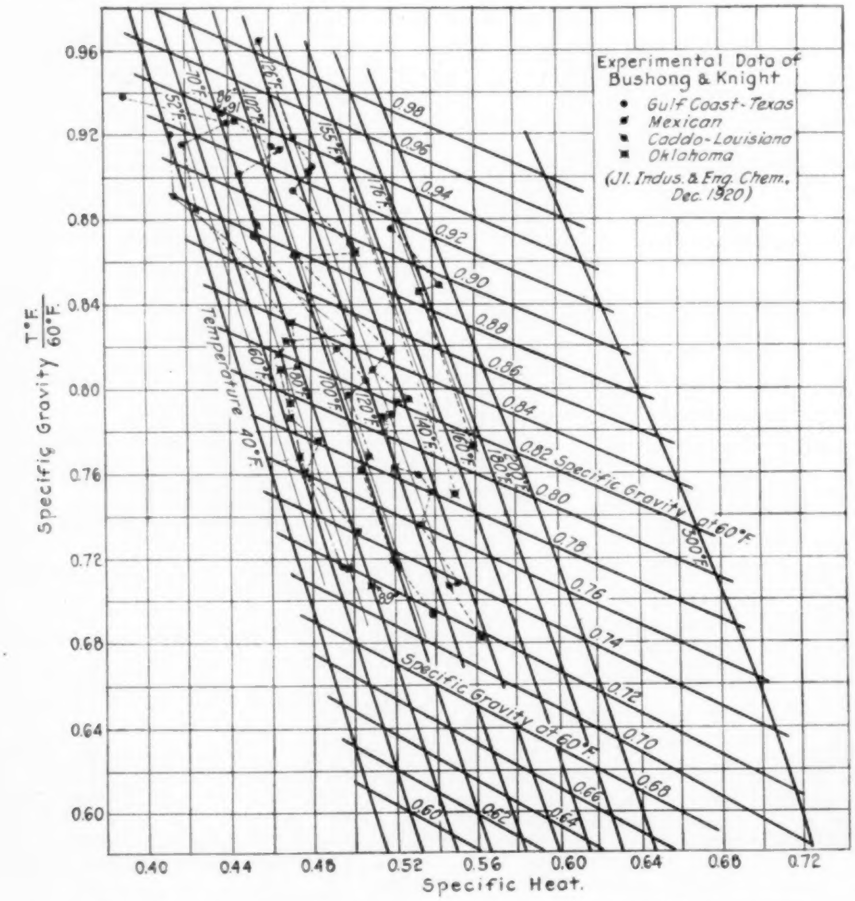

Fig. 2 Relation between Specific Gravity and Specific Heat at Different Temperatures for Petroleum Oils

Wilson and Bahlke[5] call attention to the fact that

> In using these curves it should be remembered that the density given is the density when the liquid is under its own vapor pressure, so that at relatively high temperatures (or preferably at densities below 0.45) these curves are not accurate when the pressure is much in excess of the vapor pressure.

Variation of Specific Heat with Temperature

All investigations of the influence of temperature upon specific heat show an increase of the specific heat with temperature and that it is practically a straight-line function of the temperature.[3,5,6,7,8,9]

Formulas presented by these authorities and based upon their work, while demonstrating the linear relationship, are not entirely consistent. The respective formulas deduced are as follows:

Karawajeff,[6] for heavy distillates between 100 deg. cent., and 400 deg. cent. (212 deg. fahr. and 752 deg. fahr.), found that the mean specific heat could be represented by

$$C_m = 0.4825 + 0.000385\ (t - 100)$$

and the true specific heat by

$$\frac{dQ}{dT} = 0.4825 + 0.00077\ (t - 100)$$

t being in centigrade degrees, or

$$\frac{dQ}{dT} = 0.4055 + 0.000428\ (t - 32)$$

t being in fahrenheit degrees, according to which the true specific heat at 400 deg. cent. or 752 deg. fahr. would be 0.711.

Wilson and Barnard,[7] for gasoline and kerosene, for temperatures up to 400 deg. cent. (752 deg. fahr.), (the data representing the specific heat for liquids and vapor combined and not that of the liquid alone) obtained

$$\frac{dQ}{dT} = 0.5 + 0.000333\ (t - 32)$$

t being in fahrenheit degrees. Leslie and Geniesse's data for lubricating oils, their average measurements being quoted by Wilson and Bahlke,[4] give

$$\frac{dQ}{dT} = 0.3481 + 0.00823\ (t - 32)$$

t being in fahrenheit degrees.

In none of these cases did the authors give the specific gravity or the density of the oils tested; but in general the results indicated that the specific heat of the heavier oils is lower than that of the lighter oils.

Wilson and Bahlke[5] present these curves and state that if they

> ...are used with judgment, the results will at any rate be far more reliable than those obtained by following the customary practice of using 0.5 for all specific heats. If the temperature range involved is at all large, the specific heat corresponding to the mean temperature is of course the one to employ.

The work of Bushong and Knight[3] deals with a number of oils, from different fields, and their products, and includes the data as to the density of the oils in each case. In commenting upon their results, they quote Schiff[9] as having shown

> ...that the effect of temperature upon specific heat is the same for organic liquids of the same chemical nature, specific heat being a linear function of temperature. Curves representing the specific heat of the different members of a given class are therefore parallel straight lines.

Referring to their own data and curves they state:

> They show that the specific heat of the petroleum hydrocarbons, including paraffin, is proportional to, or a function of, the absolute temperature. [This appears to be a special case in which specific heat and entropy are proportional, $aC_p/T = Q/T$, and perhaps equal.—W. R. E.] Abnormal deviations probably indicate changes in state of aggregation.

Their curves indicated so strongly that the specific heats of various hydrocarbons, as well as many other organic compounds, were directly proportional to their absolute temperatures, that it was considered by the present author as worth investigating further. To that end the available data relating to all organic liquids were collected, in general from the original sources, and plotted. It is believed by the author that, considering all of the circumstances which are involved due to the determinations being made by different authorities and methods, there is sufficient evidence to warrant the assumption, for engineering purposes at least, that the specific heat of petroleum oils may be assumed to be not only a linear function, but to vary directly with the absolute temperature.

[5] Wilson and Bahlke, The Physical Properties of the Paraffin Hydrocarbons. *Jl. Indus. & Eng. Chem.*, vol. 16, no. 2 (Feb., 1924), p. 115.

[6] Bailey and Edwards, The Determination of the Specific Heat of Heavy Mineral Oils. *Jl. Indus. & Eng. Chem.*, vol. 12, no. 9 (Sept. 1, 1920).

[7] Karawajeff, *Neftjanoje Djelo*, 1913, no. 16, through *Petroleum*, 9, 550; *Jl. Soc. Chem. Ind.*, 33, 128; *Chem. Abs.* 8, June-Oct., 1914, p. 3359; Bell, American Petroleum Refining, p. 50.

[8] Wilson and Barnard, *Jl. Soc. Automotive Engrs.*, 10, 65 (1922).

[9] Robert Schiff, Spezifische Wärme homologer Reihen flüssiger Kohlenstoffverbindungen. Ber., 19 (1866), Ref. 644.

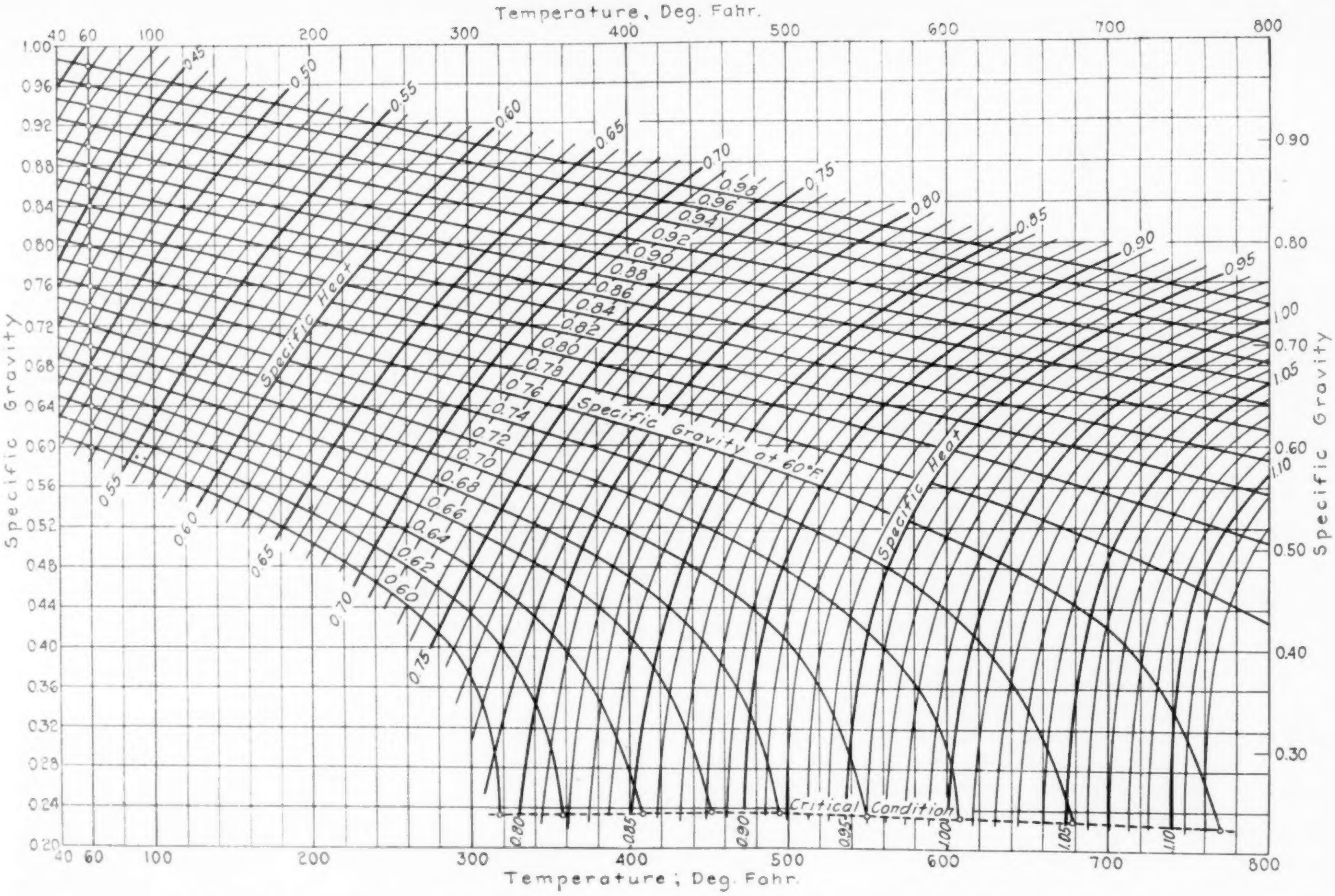

FIG. 3 RELATION BETWEEN SPECIFIC GRAVITY, SPECIFIC HEAT, AND TEMPERATURE FOR PETROLEUM OILS

Relation between Specific Heat and Specific Gravity at 60 Deg. Fahr.

Assuming the direct variation of specific heat of petroleum oils with the absolute temperature to be true, it is then possible to reduce all of the specific-heat data, at whatever temperature determined, to a common standard temperature, which has been taken as 60 deg. fahr., the standard reference temperature for all petroleum data.

Reducing likewise all specific-gravity determinations for the corresponding oils to the same temperature, the values of the specific heat were then plotted against the specific gravity, Fig. 1, and a mean curve drawn through the points. This curve represents the average relation between the specific heat and specific gravity of petroleum oils at 60 deg. fahr.

As stated earlier in the paper, the 142 points plotted cover the available data from all authorities for oils and their products from widely different fields all over the world. For the purpose of showing the broadness of these data, the points have been designated so as to indicate the authorities, and the field and nature of each oil has been set down. It will be observed that the points form a well-defined strip of definite slope. In order that one may estimate and visualize the amount of deviation from the mean, lighter lines have been drawn indicating the percentage of deviation, either + or —, and show that

$$\left.\begin{array}{r}28.3\\55.8\\73.9\\84.0\\91.3\\99.3\end{array}\right\}\text{ per cent of the points fall within }\left\{\begin{array}{c}\pm1\\\pm2\\\pm3\\\pm4\\\pm5\\\pm10\end{array}\right\}\text{ per cent of the mean}$$

and that 0.7 of 1 per cent of the points fall beyond the ± 10 per cent limit.

The formula for the average line gives

$$C_{60} = 0.7125 - 0.3105 \text{ Sp. Gr.}_{60} \qquad [1]$$

where C_{60} = specific heat at 60 deg. fahr. and
Sp. Gr.$_{60}$ = specific gravity at 60 deg. fahr.

To determine the specific heat at any other temperature the formula becomes

$$C_t = \frac{460 + t}{520}(0.7125 - 0.3105 \text{ Sp. Gr.}_{60}) \qquad [2]$$

where C_t = specific heat at the temperature t deg. fahr.

Relation between Specific Heat and Specific Gravity at Temperatures within the Range of the Experimental Data

From Equation [2] a chart has been prepared, Fig. 2, for the range of temperatures covered by the experimental data. Upon this chart have been plotted the data of Bushong and Knight's experiments, which covered the widest range of temperatures as well as a considerable number of oils and their products. The experimental points for the same temperatures have been connected together by dotted lines, and the lines for the corresponding temperatures as derived by the formula have been drawn in on the charts. There is satisfactory agreement except for 52 deg. fahr., at which low temperature difficulties and discrepancies might be expected.

Relation between Specific Heat and Specific Gravity at High Temperatures

To meet the necessity of data for the design of high-temperature apparatus another chart, Fig. 3, is presented in which the specific heat and specific gravity have been plotted against temperature up to 800 deg. fahr. From this chart reasonably accurate values may be obtained of both the specific heat and specific gravity of any oil up to a temperature of 800 deg. fahr. (or up to the critical temperature, if this is less than 800 deg. fahr.) when the specific gravity at 60 deg. fahr. is known.

In view of the high specific heats and low specific gravities in-

dicated by this chart as being reached at high temperatures, the following general findings of Pawlewski[10] upon determinations which he made of the specific heat of different Galician crudes and their products, are of interest.

1 Hydrocarbons of high molecular weight had a small heat capacity, scarcely 0.2 to 0.3 that of water.
2 Some fractions composed of light hydrocarbons had a much higher specific heat than the original crude.
3 Oils, vaselines, and paraffins, composed chiefly of heavy hydrocarbons, had a lower specific heat than the light-boiling fractions; some even lower than that obtained for the crude oil itself.
4 The specific heat of paraffins changed markedly with the temperature. At high temperatures the values approached that of water.

This chart, Fig. 3, is submitted with some hesitation, as the unstable nature of petroleum oils at high temperatures must be considered, and again because such experimental data relating to specific heats at high temperatures as are available indicate somewhat lower values. However, where such data were given, the specific gravity was not included and it was impossible to incorporate the data in this study.

More-extended experimental data may in time show an upper limit beyond which the linear relationship will not hold, and prove that a revision of Fig. 3 downward would be desirable. It is much to be hoped that such data will soon be forthcoming. Until then the high-temperature data, derived as an approximation, are of a speculative nature and must be used with caution.

Conclusion

It is trusted that the charts presented herewith may be found of some real value to the petroleum engineer and may prove of some assistance to him, when in the design of equipment it is necessary to assume values for the specific heat of the oils with which he is dealing. It is also hoped that they will serve as an incentive for further investigation in this line, especially at high temperatures.

Thanks are due to C. F. Braun & Co., for whom the study was originally made, for permission to publish the results.

Oil-Tank-Fire Boilovers

Conditions That Must Exist if a Burning Oil Tank is to Boil Over, and Which Are Never Found in Gasoline and Light-Refined-Oil Storage

By H. H. Hall,[1] San Francisco, Cal.

A BURNING OIL TANK makes a spectacular fire. For this reason, and because large values are generally involved in oil fires, the public hears a great deal more about them than their relative importance warrants. Particularly in California, where electrical storms are comparatively infrequent, an oil-tank fire is a rare occurrence when one considers the thousands of tanks in service and the millions of barrels of inflammable liquid stored.

Another feature that tends to exaggerate popular fear of oil fires is uncertainty as to just what is liable to happen when a tank burns. In one case the fire will burn quietly until nothing remains but a layer of black coke in the bottom. In the next tank, after burning for some time the oil may froth up and boil out of the tank quite violently; and when this does take place it is important to have fire walls which will prevent the burning oil from spreading in all directions. The time when this boilover may be expected is also an uncertain factor. In some cases it has taken place four or five hours after the fire started; and in other cases it has been delayed for 24 hours or more.

In an effort to find an explanation for these seeming inconsistencies, all available records of tank fires that have occurred on the Pacific Coast in the past 20 years were carefully studied. But when these data had been analyzed there still remained many apparent contradictions. It was accordingly decided that before any dependable general conclusions could be drawn, a series of tests must be run in which the different variables which might have an influence on the results could be independently controlled. These tests were undertaken with two principal objects in view:

1 To determine the physical conditions of container and contents which result in a boilover
2 To obtain data on which to base a prediction of the approximate time when an expected boilover will occur.

Equipment and Procedure

It was felt that the two most obvious factors likely to affect boilover conditions in a tank would be the temperature and physical conditions of the contents. In order to study the former it was decided to equip the test tanks with thermocouples giving temperatures at points about 8 in. apart vertically. To observe changes in the physical condition of the oil—gravity, water content, etc.—several small sample draw-off lines were connected into the tank at different levels.

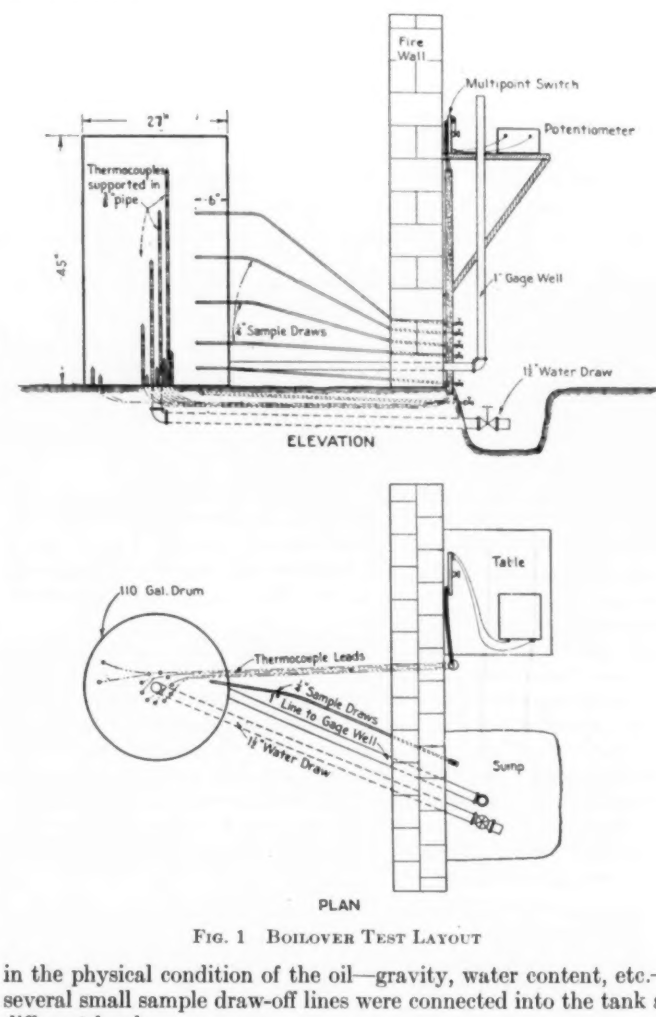

Fig. 1 Boilover Test Layout

In order to observe the influence that the size of tank might have on the behavior of the burning oil, tests were run in three different sizes, namely,

1 An ordinary 110-gal. barrel with top removed, as shown in Fig. 1

[10] Pawlewski, *Chem. Zeit. Report*, 17, no. 2, 313 (1893), through Bell, American Petroleum Refining, p. 49.

[1] Chief Engineer, Standard Oil Co. of California.

Presented at a meeting of the San Francisco Local Section of The American Society of Mechanical Engineers, March 26, 1925. Abridged by the omission of appendices giving details of the tests made and of the theory of heat-wave propagation advanced in the paper.

2 A larger drum (approximately 42 in. in diameter by 60 in. high, holding about 350 gal.) provided with a more complete set of thermocouples and sample draws, as shown in Fig. 2

3 A tank 15 ft. in diameter by 5 ft. high was used twice, in order to study the effect of a larger size on the results obtained with the smaller container. (See Fig. 3.)

The first few tests indicated that the 110-gal. tank behaved in substantially the same way as the larger sizes; and since this small tank was much easier to handle, required considerably less oil, and gave definite results in a shorter time than the larger tank, it was used for a considerable part of the investigation.

All told, a total of 104 tests were run. The oils burned included gasoline and partially refined distillate, crude oils of gravities ranging from 35 deg. to 20 deg. A. P. I., and a considerable number of fuel oils of about 17 deg. to 18 deg. A. P. I.

In the tests of crude oils, the main boilovers ranged from quiet spills in which a comparatively small amount of oil came out of the tank, to violent eruptions throwing out 75 or 80 per cent of the oil. (See Fig. 4.) In a few cases where no real boilover occurred there was a slight eruption just at the end of the tests when the oil had practically all burned out. It is thus felt that the tests accurately reproduced conditions which may be expected to occur when actual tanks burn.

If it had not been for the test apparatus (thermocouples, sample draws, etc.) with which the tanks were equipped, the whole series of 104 fires would probably have added little to our knowledge of why and when boilovers are likely to occur; for the results obtained in different tests were almost as conflicting as the records of actual fires.

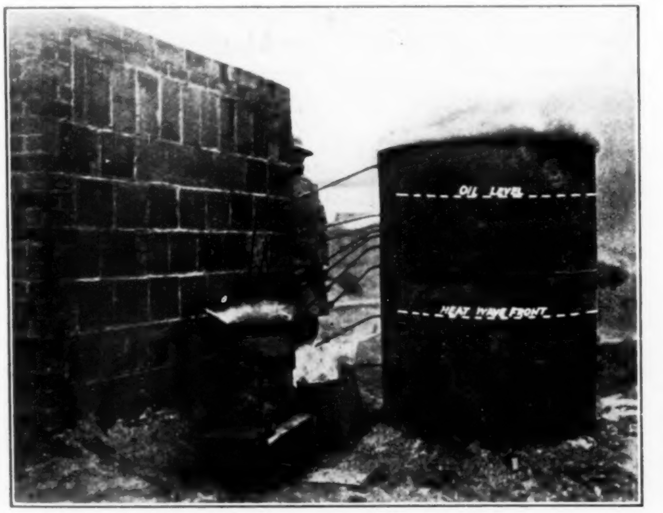

FIG. 2 350-GAL. TEST TANK BURNING FUEL OIL

(The small fires in cans were for heating sample draws to enable oil to flow. Test was run on a very cold day.)

Some tanks with water in the bottom boiled over—others did not. Most crudes boiled over, but a few did not. Most refined oils refused to boil over, but a few did, under very special conditions. However, careful analysis of the data afforded by the thermocouples, the draw-off lines, and other attachments has made it possible to reach some rather definite conclusions which are not only borne out by the tests but which agree with all available records of actual fires when these are examined in the light of the test data.

ORIGIN OF BOILOVERS

The first and most important finding is that three conditions must exist in a burning tank if a boilover is to occur: water must be present in the oil, heat must be carried down into the oil well in advance of the burning surface, and the oil must be of a viscous nature. These three conditions and the part which each plays in the production of a boilover are discussed in some detail below.

Presence of Water. In every test where a boilover occurred, water was present in the oil. In some cases free water on the bottom of the tank was also necessary to produce a boilover. This has led to the conclusion that the *oil must contain some water* if a boilover is to occur.

However, the mere presence of water does not mean that a boilover is bound to occur. The other conditions described below must also exist.

Heat Wave. A large boilover will not occur unless heat is carried down into the oil *considerably in advance of the burning surface.* This is essential because the boilover is caused by steam forming bubbles in the oil, and thus expanding it until it overtops the container. There must be enough oil on top of the steam to form these bubbles. Now oil is a notably poor conductor of heat, and it would therefore be expected that radiant heat from the flame would penetrate below the burning surface very slowly. But one of the first things observed in the tests was the tendency for what may be termed a "heat wave" to advance down to the bottom of the tank comparatively fast. Visual evidence of such an advancing heat wave may be observed in Fig. 2. At the time this picture was taken the oil level had burned down only about six or eight inches below the top of the drum; but at least the top two feet of oil had become so hot that streaks of spilled oil on the shell had been entirely dried off.

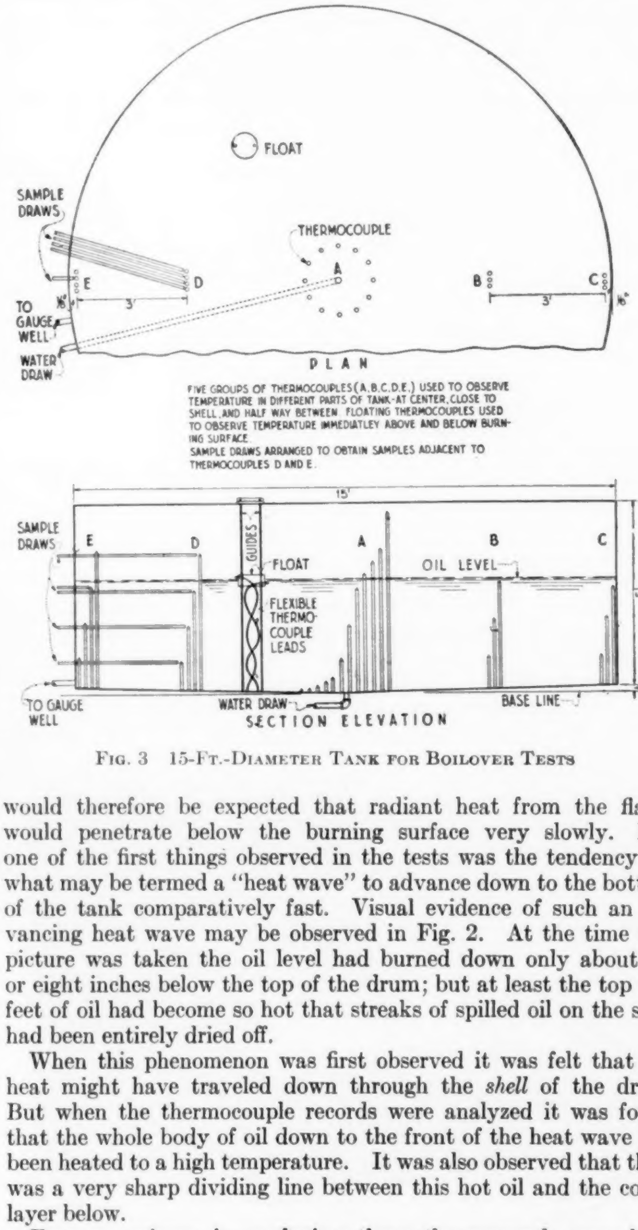

FIG. 3 15-FT.-DIAMETER TANK FOR BOILOVER TESTS

When this phenomenon was first observed it was felt that the heat might have traveled down through the *shell* of the drum. But when the thermocouple records were analyzed it was found that the whole body of oil down to the front of the heat wave had been heated to a high temperature. It was also observed that there was a very sharp dividing line between this hot oil and the cooler layer below.

For convenience in analyzing these thermocouple records, a "graphical log" was plotted for each test. Fig. 5 shows a typical log of a test in which crude oil was burned and a very sharp heat wave was formed. It will be noted that the temperature of thermocouple No. 1, which was located just under the oil surface at the start, went up almost immediately to 300 deg. fahr. In about twenty minutes the oil level had burned down to this thermocouple, and it then continued increasing in temperature until it reached about 1500 deg.—approximately the temperature that was observed in all tests where thermocouples were directly in the flames. Thermocouple No. 2, which was about eight inches below the oil level at the start, remained at an almost constant temperature for about forty minutes after the fire started. In the next ten minutes it went up from 60 deg. to 360 deg. At this time it will

be noted that the oil surface was still about seven inches above the level of this thermocouple.

About an hour after thermocouple No. 2 had shown this rapid rise in temperature, No. 3 made a similar sudden jump, going up in less than ten minutes from 70 deg. to 350 deg. At this time this thermocouple was more than eleven inches below the burning oil surface. Similar behavior was observed in the other thermocouples. About four hours after the fire was started, thermocouple No. 7, which was located just at the top of a thin layer of water in the bottom of the tank showed a corresponding sharp rise, and immediately afterward a boilover occurred. The steam which was formed when the high temperature reached the water in the bottom, rising through the 28 in. of oil which was still in the tank, caused it to foam and froth violently, and a considerable amount was thrown out of the tank.

As mentioned above, calculations based on the known conductivity of the oil indicated that such rapid propagation of heat ahead of the burning surface, could not be accounted for by conduction. In search of some other explanation the theory illustrated by Fig. 6 was evolved, and subsequently confirmed by laboratory tests.

As shown in Fig. 6, the oil in a burning tank of crude oil may be considered as divided into four layers. At the surface is a thin layer at very high temperature which is distilling, the vapors thus produced feeding the fire. Below this is an intermediate layer of hot oil (but not at such a high temperature as the thin surface layer); next a layer of cool oil in substantially its original condition both as to temperature and physical properties; and finally a bottom layer of water and sediment.

Oil, like most other substances, expands as it is heated, and its specific gravity consequently becomes less. If this expansion were the only action to which the oil was subjected, the hottest oil would be the lightest, and would therefore remain at the surface. But the thin surface layer which is feeding the fire, besides getting hot, is also undergoing another process—that of distillation. This action tends to make the to player grow heavier, as it is the lightest fractions that are distilled off to feed the flames.

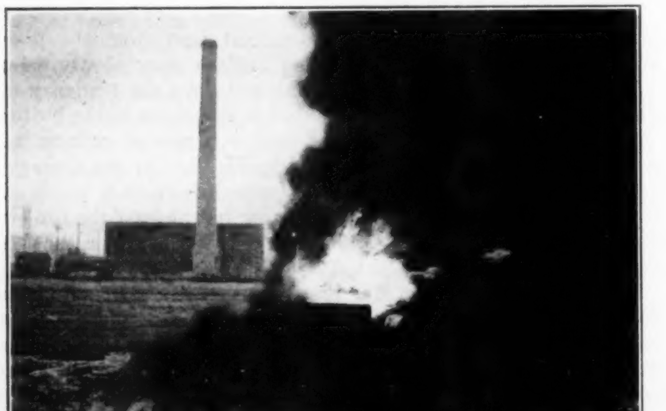

Fig. 4 Maximum Intensity of Boilover of Test Tank

Eventually this action of distillation overcomes the lightening effect of the heat, and portions of the top layer, which is at the highest temperature in the tank, actually become heavier than the somewhat cooler layer next beneath. These heavy ends then sink through the hot oil below, carrying a considerable quantity of heat down with them. When they reach the top of the layer of cold oil, further sinking is prevented in two ways:

a The gravity of the cold oil may be higher than that of the hot heavy ends

b Even if it is not, there will be a certain amount of ebullition due to the fact that heat in these heavy ends will vaporize some of the lightest fractions in the cold oil, and will also vaporize some of the water that may be suspended in this oil. This tends to mix the hot ends with the upper portion of the cold oil, with the result that some of this cold oil is brought up to the temperature of the hot layer immediately above.

Thus continuous circulation is set up as indicated by the arrows in Fig. 6. Heat from the fire is carried down into the cold oil;

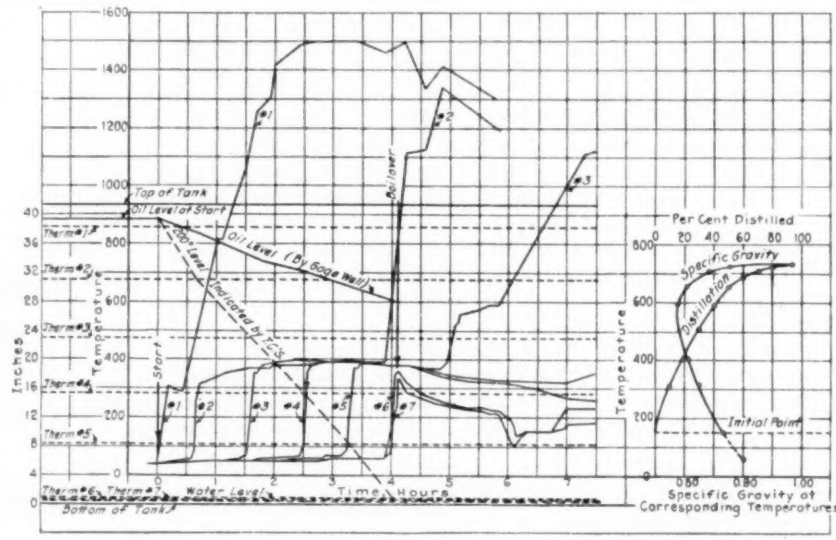

Fig. 5 Boilover Test No. 9—Southern California Crude Oil

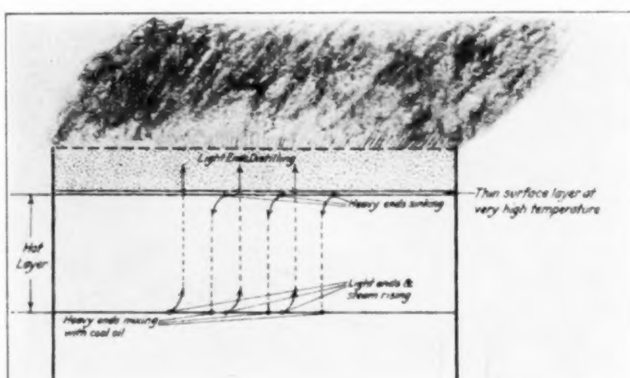

Fig. 6 Process of Heat Transfer by Heavy Ends

the lightest fractions of this cold oil are distilled, the vapor rising to the surface, and the remainder is warmed to the temperature of the hot layer. The result is that the depth of the hot layer continually increases; that is, the "high-temperature front" penetrates further and further ahead of the burning surface, and eventually reaches the water in the bottom of the tank at a time when there is still ample depth of oil in the tank to froth and boil over as the steam rises through it from the water being vaporized in the bottom.

This explanation of the mechanism by which the heat wave advanced was subsequently confirmed by special laboratory distillations, which were made on every one of the test oils. The results of such a distillation test of the oil burned in Test No. 9 are plotted at the right-hand side of the graphical log of that test reporduced in Fig. 5.

It will be noted that as this particular oil is heated up, it keeps growing lighter up to about 600 deg. fahr., at which time about 40 per cent has been distilled off. From then on the burning layer grows heavier until at about 730 deg. it is as heavy as the original

cold oil. By that time 60 per cent of the original top layer has been burned. In all probability, before this degree of distillation has been reached, half the top layer will have sunk into the hot oil below it, and will have carried some of this approximately 700 deg. temperature down with it to the top of the original cold oil.

Further confirmation of this theory that a heat wave is carried down into the burning oil by the settlement of heavy ends from the distilling surface layer, is afforded by the fact that when refined oils containing only a small portion of heavy ends are burned, a heat wave either does not form at all, or if it does start, it does not persist to the bottom of the tank. Examples of these two cases may be observed in the graphical logs of Tests Nos. 4 and 7, Figs. 7 and 8.

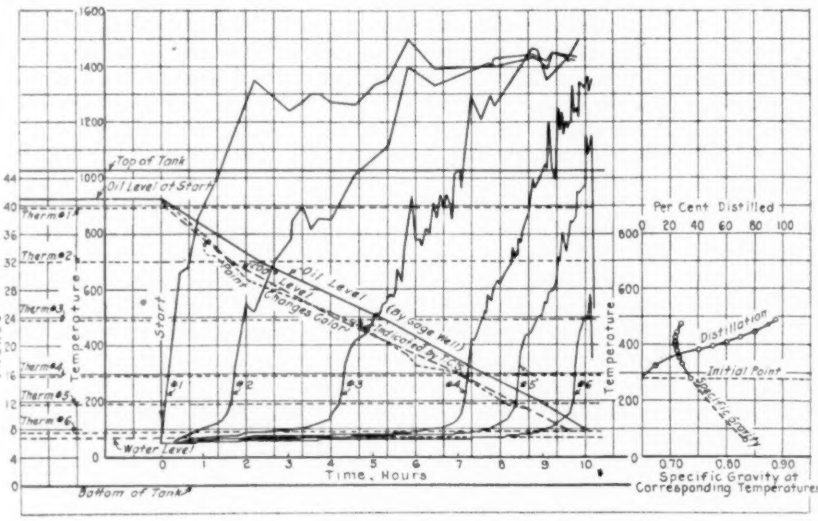

FIG. 7 BOILOVER TEST NO. 4—WATER-WHITE DISTILLATE

The oil burned in Test No. 4 was "water-white distillate," a crude kerosene before receiving its final treatment. From the distillation curves of this oil, which are shown in Fig. 7, it will be noted that this specific-gravity curve has only a slight inflection at the very end, which indicates that the oil contains practically no heavy fractions. As would be expected from this condition, the thermocouple curves show the complete absence of any heat wave when this oil burned. For example, thermocouple No. 4 increased only a few degrees for the first $6^1/_2$ hours of the test. By this time the oil level had burned down to within about 3 in. of this thermocouple. It was thus evident that heat was being carried down into the oil almost entirely by conduction, and consequently that the high temperature could advance only a few inches ahead of the burning surface. When the heat finally did reach the layer of water in the bottom of the tank, there was not enough oil left to cause any appreciable eruption. The fire simply sputtered out.

In Test No. 12, the graphical log of which is shown in Fig. 8, crude naphtha was burned. The distillation curves for this oil indicate that it contained a somewhat greater portion of heavy ends than did the water-white distillate burned in Test No. 4. Consequently a heat wave started to form, but before it had reached the bottom of the tank it died out. There were two principal reasons for this: the heavy fractions were not enough heavier than the oil in the hot layer to cause rapid circulation; and the complete absence of water from this oil eliminated any tendency for steam to rise through the hot layer and thus reduce its effective specific gravity. The net result was that heat did not get down to the water in the bottom of the tank until most of the oil had been consumed; so that, as in Test No. 4, the fire finally sputtered itself out.

From these records of three typical tests it is clear that if a boilover is to occur, the oil burning must have distillation characteristics that will permit a heat wave to persist all the way to the water that may be at the bottom of the tank.

Viscous Oils. The third requirement is that the oil, or at least the sediment at the bottom of the tank, shall be of a viscous nature.

As explained above, a boilover occurs when water is converted into steam by the heat that is carried down through the oil, this steam creating a foam or froth as it rises through the oil above. If the oil is of a non-viscous character, so that it will not foam as steam rises through it, a boilover is not liable to occur.

This is of interest mainly in connection with partially finished refinery stocks, such as crude naphtha. These may contain enough heavy ends to set up a heat wave; but if nothing but clean water is in the tank bottom, a boilover is not liable to occur. However, if there should be a few inches of sticky bottom settlings, this may produce enough froth to cause a boilover.

So much for the *conditions* under which a boilover may occur. The next important thing to ascertain is *when* the boilover is to be expected.

TIME OF BOILOVER

A large boilover will not occur until a heat wave has reached the bottom of the tank, or has at least progressed to the top of whatever layer of wet settlings there may be in the bottom. Hence, to predict when a boilover is likely to occur in any particular fire, it is important to know the progress of the heat wave. The rate at which this wave advances is influenced by so many factors—the distillation characteristics of the oil, its water content, the size of the tank, etc.—that it is impractical to make any general statements regarding the rate of advance which may be expected in different oils. But by actually observing in the early stages of a fire the rate at which the wave is progressing—if the oil is such that a heat wave forms—a reasonably accurate prediction may be made of the time when a boilover is to be expected.

Various means of observing the progress of the wave were noted in the course of the tests. Simply looking past the shell of the tank may give the desired information; for down to the level of the front of the heat wave there is an apparent undulation of the air resulting from the heat radiating from the shell—this phenomenon being similar to that observed when looking along a pavement on a hot day. At night, or where atmospheric conditions are not favorable to this means of observation, water sprayed against the shell will steam down to the bottom of the hot layer; old oil on the shell will dry out as the hot level advances downward (as shown in Fig. 2); and, of course, where conditions permit approaching the tank, feeling the shell will indicate when the heat wave has advanced down within reach.

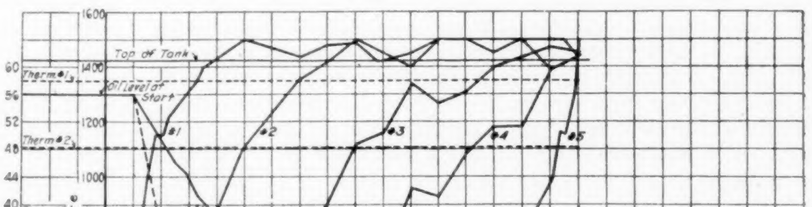

FIG. 8 BOILOVER TEST NO. 12—CRUDE NAPHTHA

Most of these methods are only approximate and may not give very reliable results. In the course of the tests it was found that a special temperature-indicating paint, made of a pigment which

changes color when its temperature rises above 150 deg. fahr., is a very satisfactory and practical method of accurately following the progress of the heat wave. Probably a stripe of this paint could be applied in most cases after a tank is on fire, by approaching from the windward side and using a brush attached to a pole for painting a stripe down the side. Three-quarters of a pound of cuprous mercuric iodide finely ground, mixed with one-quarter of a pound of diatomaceous earth as a filler, and stirred into one pint of linseed oil or equivalent will make enough paint for two stripes extending the full height of a 30-ft. tank. In view of the importance of knowing when to expect a boilover from a burning tank, it would seem well worth while to keep these ingredients for making up a small quantity of temperature-indicating paint on hand wherever there are large tanks containing crude or fuel oils.

Drainage

In addition to investigating the cause of boilovers and the time at which they may be expected to occur, some time was devoted during the tests to an endeavor to find a means of preventing them.

One of the most obvious methods is to endeavor to remove the water. This was tried even to the extent of building a special cone-shaped bottom and attempting to keep the water drained off right up to the moment that the heat wave reached the bottom. This process was successful in a few cases, but even it could not be counted on.

Nearly all crudes contain some water, either in emulsion or suspension, and as the heat wave comes down through the crude, some of this water gradually settles out, but not immediately. The result is that the water in the bottom of the burning tank is being continuously augmented; and as it expands some 1700 times when turned to steam, it takes very little of it to cause a boilover. In actual practice, tank bottoms are so uneven that it would not be possible to count on completely draining out all the water. But the less there is on the bottom when the heat wave reaches there, the less violent the boilover will probably be. It is therefore good practice to drain a tank of burning crude oil as rapidly as possible through the lowest available connection—preferably a water draw in the bottom. This drainage should be continued, if practicable, until the heat wave reaches the bottom.

Residual fuel oil, as distinguished from crude, contains no water when it leaves the still; but nearly all fuel oil contains some water when it reaches the consumer. One of the chief sources of this water is the common practice of transporting fuel oils in tankships. These vessels generally carry salt-water ballast when returning from the point of delivery; and it is impractical to get the last traces of this water out before the vessel is reloaded. So some of it gets mixed with the oil during transportation; and more water may get in from leaky steam-heating coils, leaky tank roofs, etc. In many cases the water content of fuel oil will be less than $^1/_2$ of 1 per cent; and the tests indicated that a fuel as dry as this would probably not boil over. But this is a condition that can hardly be counted upon. It is generally safest to assume that, if a fuel-oil tank is fired, it may contain enough water to cause a boilover, and to drain the bottom of the tank continuously until the heat wave reaches there.

Water settles out of fuel very slowly, so that there may be enough still suspended just below the front of the heat wave to cause a boilover in spite of this drainage; but as in the case of crude oils, any water that can be removed by drainage will reduce the violence of the boilover, if it does occur.

* * * *

Replying to questions propounded after presentation of the paper, the author pointed out that water was almost always present in crude oil—sometimes only in small quantities, but only a very small percentage of water in an oil was necessary to cause a boilover. In the case of some oils that had considerable water in suspension, slop-overs had occurred before the heat wave reached the bottom of the tank; those responsible for the safety of men working near a burning tank should be on the look-out for such slop-overs after the tank had burned more than a few hours. However, the real boilover would not occur until the heat wave had traveled down to water which may be in the bottom of the tank.

Fuel oil, as it came from the stills, was free from water; but in handling, it might pick up enough water to cause a boilover, so this contingency should be kept in mind when a fuel-oil tank burned. However, fuel oil was so hard to ignite that there were extremely few records of fuel-oil tanks burning anywhere in the United States.

Refined oil would not boil over, because it did not have the heavy ends necessary for a heat wave, and because it was not viscous, even though water was in the bottom of the tank, which was often the case in marketing tanks.

Regarding the effect of fire on the tank, the author said that he had never known of a riveted or welded tank breaking or the seams parting in any fire. In the tests, no bulging or other changes due to heating had been observed in the sides of the tank.

Answering a question regarding certain actual fires in which more than one boilover had occurred, the author said that in many cases the first boilover spilled some of the contents out of the tank but apparently did not evaporate all the water in the bottom of the tank; after this the oil continued to burn and eventually boiled over again. In a number of cases, particularly where heavy oils had burned, the first boilover had created a foam or froth which had actually extinguished the fire.

Regarding the foam system for extinguishing fires, his company's two actual experiences on large gasoline-tank fires had been entirely successful. He pointed out that this had been accomplished with foam systems in good working order and ready to start the minute the fire was reported; that this was quite a different matter from attempting to put out a fire with an improvised foam system, which had often proven unsuccessful.

According to information in the hands of the British Home Office (corresponding to the office of the Secretary of the Interior in the United States), there was an increase in the number of cases of lead poisoning in ship-scrapping yards during the last few years. The industry is carried on in about seventy yards, some of them temporary in character and varying very much in size. The cases occur among burners or their assistants employed in cutting lead-painted and red-leaded plates by means of an acetylene flame, and are caused by the inhalation of lead fumes. There was one case in 1919, three in 1920, and 131 in 1924.

Under high magnification (600 diameters) the fume from cutting —which experiments by the government chemist show is so fine as to be completely held back only by a layer of cotton wool 6 in. thick—is seen to consist of an enormous number of translucent, colorless particles, chiefly 0.5 of a micron ($^1/_{50,000}$ of an inch) and less in size, discrete, but so dense as almost to be touching, irregular in form and apparently more flaky than globular. Such microscopical examination indicates that the fumes (1) are particulate in character; (2) may be present and may reach considerable density though not obvious even in bright sunlight; and (3) are much more dense in confined or sheltered places.

There is no doubt that the whole of the symptoms are due to the inhalation of fume which is liberated at the high temperature of the oxyacetylene flame as it comes into contact with lead-painted surfaces or with red lead. Experiments carried out in the government laboratory abundantly prove this and show that the amount of lead breathed daily by an oxyacetylene burner is about 25 times as great as the minimum dose of lead which, if inhaled daily, will in time cause chronic lead poisoning.

The risks occur chiefly in confined or sheltered places, and on this account the general method of procedure is to "open up," that is, to begin burning on the deck and work downward in order to avoid such places. It has not so far been found possible to apply to this process the remedy usually adopted to remove poisonous dust or fumes, namely, localized exhaust ventilation. Nor can the wearing of respirators of the ordinary type be recommended. Owing to the nature of the fume the ordinary respirator affords little or no protection, and, by reason of the false sense of security it gives, may even result in increased risk to the worker. For oxyacetylene cutting in confined or sheltered places the only suitable type of respirator is a breathing apparatus with tube attachment several feet in length, so arranged that the operator breathes fresh air through the free end. Certain precautions are suggested and the employment of young persons as lead burners or as assistants is depreciated. (*Shipbuilding and Shipping Record*, May 7, 1925, p. 560.)

The Utilization of Wood Waste as Fuel in Steam Power Plants[1]

The utilization of wood waste from the lumber-manufacturing industry as a fuel for power-producing purposes offers to the engineer a series of problems as unique in character as they are important in their economic scope. The yearly output of such waste actually employed to produce power in the Pacific Northwest is the equivalent of about two million tons of good steam coal or seven million barrels of fuel oil. The intrinsic heating value is low, and its bulk, high moisture content, and irregular texture call for the solution of difficult problems in handling, storing, and firing, with equally important questions in furnace design, draft control, and cinder elimination to be solved. The present efficient types of furnaces used with the fuel are the result of a long period of evolution, wherein the peculiar nature of this fuel was studied in its relation to known principles of combustion, with the development of a distinct and characteristic line of engineering methods which has resulted in the ability to design and operate wood-waste-burning plants having an efficiency and capacity comparing favorably with other steam power plants.

Combustion of Wood Waste from Lumber-Manufacturing Plants

By H. W. Beecher,[2] Seattle, Wash.

The purpose of this paper is to cover in a general manner combustion characteristics of wood wastes from the lumber-manufacturing industry as a boiler fuel and the adaptation of wood waste to such uses. The sawmill refuse or waste from the lumber-manufacturing industry has, in general, been in greater quantity than required for the production of power for sawmill operation and steam for mill process work, and therefore efficiency of combustion of such fuel has been of little importance.

In most cases efficient combustion of fuel under the boilers in such plants has not been desired as it would result in a greater amount of waste to destroy in refuse burners with corresponding higher handling and maintenance costs. There have been many changes in the sawmill plants, the modern plant having discarded the slide-valve and later Corliss-engine drives through lineshafting for the steam-turbine-driven generator and electrified mills. With this change in prime mover and method of power transmission, there has come the demand for higher steam pressures, compact boiler rooms, more efficient fuel handling, and the return-tubular-boiler installations are gradually being replaced with the more efficient water-tube boilers.

Uses of Wood-Waste Fuel

The use of hog fuel in plants not allied with the lumber industry has been rapidly increasing and has been largely a product of the last few years. Many of the public-utility companies and industrial plants in the Northwest are securing the bulk of their steam-generated power from power plants burning hog fuel. Over 850,000 units[3] of hog fuel were used in the Northwest during 1924 in such steam production. This quantity does not include slabs or mill end sold as such.

As the cut of the Washington and Oregon mills for the last four years averaged about 10,000,000,000 ft. and approximately half a unit is available per thousand feet cut, it is evident only a small part of the wood waste reaches a market in the form of hog fuel. The 850,000 units used by public utilities and industrial plants is roughly equivalent to 2,100,000 bbl. of fuel oil, or from 600,000 to 700,000 tons of the quality of steam coal on the northwestern market.

By virtue of the fact that the disposal of this refuse is an item of expense to the lumber-manufacturing plants, the wood waste is available for sale at prices which make it a commercial competitor of coal and oil, and provide for the sawmill an additional source of revenue. Because of its bulk per unit of heat and the difficulty in handling, the price obtained by the mill is a comparatively small percentage of its cost delivered at the boilers.

The increase in the use of wood refuse in these plants has produced an additional revenue for the lumber industry. There are very few sawmills on tidewater that are not taking advantage of the possible sale of wood refuse in the form of hog fuel. The amount of hog fuel available for sale per thousand feet of boards cut is variable, and depends upon the type of mill and the character of logs received. There are some mills that report as much as a unit of hog fuel available for sale per 1000 ft. of logs scale. There are other mills that report as little as one-third unit. It can be conservatively assumed that the mills will average one-half unit per 1000 ft. On this basis there are available in the mills adjacent to possible industrial uses of mill refuse, approximately 5,000,000 units per year. The above figure includes much wood now sold in the form of slabs and mill ends for domestic heating. It does not include the wood waste used in the mills in the production of power for mill operation. As hog fuel is now priced by the mills, it can be sold, where a market is available, to net the mill owner from 50 cents to $1.00 extra per 1000 ft. of lumber produced. By converting this wood waste into steam at the plant and thus avoiding handling costs and producing therewith electrical energy by means of large-size turbo-generators, it is possible to produce from 600 to 750 kw-hr. per unit. It was consideration of the possibilities of such local production of salable electric energy that prompted The Long-Bell Lumber Company to install a modern steam power station in which to convert a large portion of their mill waste into electrical energy.

Hog Fuel Defined

The wood waste from the lumber-manufacturing industry is commonly referred to as "hog fuel." This term is incorrect as applied to all of the refuse sold and correct only in so far as it applies to that portion which has been manufactured by the process of feeding slabs, edgings, trimmings, etc. into a mechanical contrivance to reduce this wood to a uniform small size and termed a "hog." There are four types of hog on the market. One differs but slightly from the chipper used to prepare wood in a paper mill for the digester in the production of sulphite pulp, and consists of a steel disk to which are attached knives. A second type consists of two concentric cones bearing knives which revolve in a conical-shaped housing. A third hog is one in which a cylinder fitted with a row of knives revolves in a cylindrical housing. The fourth type is known as a "hammer hog," in which the wood is broken up by the impact of a series of hammers operating against the edges of anvils. There are limitations as to the shape and character of the wood that can be fed to each of these types of hogs. The selection of the right hog for the duty imposed is important. All knife hogs are subject to dulling caused by tramp iron or other foreign material, and require frequent change of blades in order to maintain a uniform product. As soon as the knives are dulled there is a tendency for the wood to come through in shreds instead of chips, and these shreds may be of such length as to interfere materially with the handling of the fuel, and in particular with its discharge through independent openings in the conveyor system. It is sometimes necessary to "rehog" fuel, and in such an event two types may be used to advantage in series.

The expression "hog fuel" has by sufferance been extended to include not only the material that has been passed through a hog but also shavings from planing mills, sawdust from saw kerfs, bits of bark, chips, and other small recovered products from the manufacture of lumber. Hog fuel as sold for commercial purposes therefore varies materially in its size, the amount of voids, and the proportions of wet and dry wood it contains.

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[1] Symposium presented at the Portland Regional Meeting of The American Society of Mechanical Engineers, Portland, Ore., June 22–25, 1925. Arranged for and coördinated by H. S. Bastian, of Chas. C. Moore & Co., Portland, Ore., Mem. A.S.M.E.

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[3] One unit equals 200 cu. ft. See Methods of Measurement on p. 546.

Methods of Measurement

On account of the difficulty in weighing and determining moisture in a material which is comparatively bulky and in which the heat-unit content per cubic foot is small, and also influenced by the comparatively low price obtained by the mill per unit of heating value, custom has established that this material shall be sold and purchased on a cubic-foot basis rather than on a B.t.u. basis. This method is subject to error and considerable variation in fuel value per dollar paid, first, because of the varying proportion of dry wood delivered per cubic foot, and second, because of the material effect on the available heat per pound of dry wood due to the moisture content of the wood as delivered and the necessity of evaporating the contained moisture with the loss of the heat required to raise the temperature of such moisture above that of the surrounding air, evaporate it into steam, and superheat it to the temperature of the outgoing gases. Table 1 shows the marked variation in available B.t.u. with varying boiler efficiency and varying percentage of moisture. In this table the available heat is defined as the heat left in the fuel for evaporative purposes after deducting the heat necessary to heat, evaporate, and superheat the moisture in the fuel to an assumed stack temperature of 550 deg., and is computed on the basis of 8500 B.t.u. per lb. of dry fuel. While tests show that the B.t.u. per lb. of dry fuel in most soft woods will run closer to 9000, the low value is assumed to account for variation in stack temperature, resin content, incoming-fuel temperature, etc. and the available heat as calculated and given in Table 1 is still slightly conservative. The boiler efficiency used in this table is not based on the ratio between the total heat put into the furnace and the total heat represented in the steam generated in the boiler, but, for convenience in calculation, has been based on the heat available for production of steam.

TABLE 1 AVAILABLE HEAT AT VARIOUS BOILER EFFICIENCIES AND MOISTURE CONTENTS IN FUEL

Per cent moisture by wt., P	Total heat available H_a, B.t.u. per lb.	Boiler efficiency, per cent			
		40	50	60	70
10	7523	3009	3760	4514	5266
20	6546	2618	3273	3928	4582
30	5569	2228	2784	3341	3898
40	4593	1837	2297	2756	3215
50	3615	1446	1808	2170	2531
60	2638	1055	1319	1583	1847
70	1661	664	831	997	1163

Formula: $H_a = 8500\ (1-P)-P(970.4 + 150 + 150)$

If the wood were fed into the furnace as solid wood, based upon an assumed specific gravity of 0.40 for a mixture of dry Douglas fir and hemlock the corresponding quantity of fuel required per developed horsepower with moisture content as given and boiler efficiency based on available heat in the wood, would be as given in Table 2.

TABLE 2 CUBIC FEET OF SOLID WOOD PER BOILER-HP-HOUR AT VARIOUS EFFICIENCIES AND MOISTURE CONTENTS IN FUEL

Per cent moisture by wt.	Boiler efficiency, per cent				
	40	50	60	70	100
10	0.400	0.320	0.267	0.228	0.160
20	0.409	0.327	0.273	0.234	0.164
30	0.421	0.337	0.281	0.240	0.168
40	0.437	0.350	0.291	0.250	0.175
50	0.463	0.370	0.309	0.264	0.185
60	0.508	0.406	0.339	0.290	0.203
70	0.605	0.484	0.403	0.346	0.242

Formula: $V_w = 33{,}465\ (H_a \times W_v)$

Table 3 is derived from Table 2, using a factor of $2^1/_4$ to convert from solid wood to hog fuel. This is an arbitrary average value and is subject to considerable variation. The author has known cases where this factor has been computed to be as low as 1.8, also others where it has reached as high as 3.8. The variation in this factor is largely due to the percentage of fines or saw-kerf dust, the condition of hog knives, and the proportion of planing-mill shavings. It is also affected by the period of time in which hog fuel has stood in containers and the jarring or packing to which it has been subjected.

TABLE 3 CUBIC FEET OF HOG FUEL PER BOILER-HP-HOUR AT VARIOUS EFFICIENCIES AND MOISTURE CONTENTS IN FUEL

Per cent moisture by wt.	Boiler efficiency, per cent				
	40	50	60	70	100
10	0.900	0.720	0.600	0.513	0.360
20	0.920	0.735	0.615	0.527	0.369
30	0.947	0.758	0.632	0.540	0.378
40	0.985	0.787	0.655	0.563	0.394
50	1.042	0.833	0.695	0.594	0.416
60	1.145	0.913	0.763	0.653	0.457
70	1.362	1.090	0.910	0.778	0.545

Formula: $V_H = V_w \times K$

where H_a = available heat, V_H = cu. ft. per hr. per b.hp. (hog fuel), P = per cent moisture, W_v = wt. of 1 lb. fuel at various moistures, V_w = cu. ft. per hr. per b.hp. (solid wood), K = constant = 2.25.

Table 3 is useful in determining proportions of furnaces and quantities of fuel fed into furnaces per hour for a given output.

It is of interest to note that as the percentage of moisture content by weight is increased, not only does the boiler efficiency, based on B.t.u. fed into the furnace, become less due to the difference between total and available heat, but also the efficiency based on available heat is decreased. In the course of the author's experience with the combustion of hog fuel it has been determined from various tests that such variation in efficiency does exist, but the data so obtained are sufficiently influenced by other factors to prevent his presenting in this paper any authentic curve on which reliance could be placed in prophesying probable variation of efficiency based on available B.t.u. with variable moisture content. In general, resinous woods burn better than those containing less resin, but in the sale and purchase of wood refuse little account has been taken of the resin content or of whether the refuse is of fir, hemlock, spruce, cedar, or alder.

For convenience in the purchase and sale of wood refuse, the unit of hog fuel has been taken as 200 cu. ft. Because of variation in voids, weight of dry wood, and moisture content, the weight of a unit may vary from 2500 to 5000 lb. The average unit will weigh in the neighborhood of 4000 lb. and frequently computations are made on the basis of a unit weighing 4000 lb. and containing approximately 42 per cent moisture. The moisture content, as usually expressed, is a designation of the percentage by weight of water contained in a unit weight of fuel as received. Samples of wood refuse have been placed in truck boxes containing 200 cu. ft. and driven over rough roads for the purpose of determining the amount of shrinkage with agitation. Such shrinkage is somewhat dependent upon the shape of the container, but, in general, may be said to amount to from 10 to 15 per cent. A further decrease in volume has been noted due to settlement over a period of 24 hours. This is entirely due to the decrease in voids resulting from the weight of the fuel.

Results Obtainable

The wide range of variation in available heat makes it difficult to make comparisons or prophesy the evaporative results obtainable from hog fuel in terms of pounds evaporated per cubic foot or per unit, but if it were practicable to buy and sell fuel on a B.t.u. basis as determined by weight and moisture content, valuable data could be obtained from comparison of evaporations secured in various plants. Actual results secured in practice vary anywhere from 8000 to 13,500 lb. evaporated from and at 212 deg. per unit of 200 cu. ft. of hog fuel. There have been a few tests made in which the fuel has been weighed and the moisture content determined, and the results have shown evaporations varying from 3 to 6 lb. of water from and at 212 deg. per lb. of dry fuel. In a few plants where the hog fuel is converted into electrical energy, careful check has been kept on the kilowatt-hours obtained per unit of hog fuel. The results so obtained vary from 200 to 750. A modern steam station with economizers and high pressure and superheat should be able to obtain between 1000 and 1100 kw-hr. per unit. Tests made to determine the CO_2 content of flue gases from hog fuel show wide variations not only in various-shaped furnaces but also in the results to be obtained with any individual furnace. The conical-shaped pile in which hog fuel is consumed in the furnace does not lend itself to uniform flue-gas analysis. There are times when big blowholes develop, through which excess air passes in large quantities. There are other times when the fuel avalanches, covering up the spaces through which air is normally admitted, and insufficient air for combustion is supplied. To alleviate this difficulty in part, modern furnaces are designed to admit a large portion of the air through openings in the furnace front above the grate line and commonly referred to as "overdraft air." There can be no assurance that this air will properly mix with the gases from the fuel and there is consequently continuous lan

ing of the gases, so that any flue-gas analysis could not be made on a representative or average sample.

Considerations Affecting Efficient Combustion

In the burning of wood fuel there is little combustion of fixed carbon until the volatiles have been eliminated. The ultimate analysis of an average sample of dry wood is approximately as follows:

	Per cent
Carbon	50.0
Hydrogen	6.0
Oxygen	43.5
Nitrogen (less than)	1.0
Ash	balance

An approximate analysis on a dry-wood basis would show in the neighborhood of

	Per cent
Volatile	81.5
Fixed carbon	17.5
Ash	1.0

The fuel does not materially reduce in volume by the driving off of volatile and moisture content, the cinders remaining approximately in their original shape, and sometimes even swelling. As the fuel is consumed in conical piles the air for reduction of the fixed carbon must of necessity pass through the fuel bed, and the variation in draft resistance through different parts of conical piles reduces materially the rapidity of fixed-carbon oxidation in the center of the pile. An inspection of the grates from the ashpit reveals that there are live coals of cinder being consumed over the entire area, the brightest portion appearing around the edges.

Engineers in determining capacities of boiler installations have frequently referred to the ratio between heating surface and grate surface. This is incorrect, as the active area of combustion is the surface of the cone rather than the area of the grate which supports it. The area of active combustion is the portion of the conical surface through which the maximum quantity of air is admitted. Considerations of the variable draft resistance of conical piles led the author to the study and development of a step-grate furnace and its application to hog fuel, as later described in this paper.

The high volatile content of fuel referred to above has an important bearing on efficiency of combustion as it is necessary to secure an intimate mixture of rapidly-driven-off volatile with the overdraft air. The considerations affecting the volatile content were thoroughly covered in paper on special boiler fuels presented by Darrah Corbet before the A.I.E.E. in August, 1920.

The analyses of flue gases commonly reported only show determinations of carbon dioxide. The conditions of operation and the high volatile content of wood refuse make the determination of carbon monoxide of special importance in securing the highest efficiency. In an attempt to cut down on the excess air and secure high carbon dioxide determination, greater losses frequently result from stratification of gases having a high proportion of carbon monoxide. In the step-grate furnace, later described, as installed in a paper-mill plant, with fuel containing from 55 to 60 per cent moisture, it has not been difficult to obtain from 17 to $17^1/_2$ per cent CO_2 with but a trace of CO.

Wood refuse, on account of its high oxygen content, is capable of producing, without excess air, over 20 per cent CO_2 by volume. One should expect to obtain from 15 to 16 per cent CO_2 with the step-grate furnace, corresponding to from 20 to 30 per cent excess air. Table 4 prepared from the average analysis quoted above shows the percentage of CO_2 by volume for certain percentages of excess air.

TABLE 4 PERCENTAGE OF CO_2 BY VOLUME FOR VARIOUS PERCENTAGES OF EXCESS AIR

	Excess air, per cent					
	0	20	40	60	80	100
CO_2	20.37	16.96	14.53	12.71	11.29	10.16
O_2	0.00	3.50	5.98	7.85	9.31	10.46
N_2	79.63	79.54	79.49	79.44	79.40	79.38
	100.00	100.00	100.00	100.00	100.00	100.00

The number of pounds of air required for the combustion of various fuels is approximately 7.65 for each 10,000 B.t.u., irrespective of the ratio of carbon to hydrogen. While the pounds of air per pound of fuel varies considerably with the various fuels, this fixed relation between weight of air and B.t.u. simplifies combustion calculation.

Draft

The draft required for the combustion of wood refuse is largely dependent upon the shape and arrangement of the furnace. The draft losses through the boiler correspond very closely to those obtained with coal. The draft losses through the grates and furnace are decidedly variable. On account of the furnace admitting most of the air as overdraft air, the velocity through the fuel bed, and therefore the draft loss through it, is minimized. In order to obtain high rates of combustion with wet fuel it is necessary to provide liberal draft equipment.

Types of Furnace, Present and Future

The general design of furnaces has undergone considerable modification in recent years. Originally wood refuse was fed through openings on the two sides of the shell of return tubular boilers, immediately in back of the front wall of the boiler. This meant that the combustion took place immediately under the shell of the boiler, and as the fuel piled up against the side walls there was comparatively little brickwork to radiate heat on to the green fuel as it came into the furnace, and the cold shell of the boiler absorbed heat rapidly through radiation. Under such adverse furnace conditions the capacities obtained were comparatively low, the efficiency was poor, and the boilers smoked badly.

It is commonly considered that the smoke from the combustion of wood is a result of insufficient air supply. However, this may not be the cause, as smoking may occur due to stratification. The smoke is a product of the volatile portion of the fuel and not the result of improper combustion of the fixed-carbon content. In the burning of volatiles the hydrogen seeks and first unites with the oxygen, and unless this takes place in a zone of temperature sufficiently high and in the presence of additional oxygen, the finely divided carbon forming the smoke will reach the tubes without uniting with the oxygen.

The next step was the use of Dutch-oven furnaces where the fuel was fed through openings in the arch. In this type of furnace the conical pile or piles formed on the grate do not extend up furnace side walls, so it provides larger exposed areas of hot brickwork. Automatically the length of gas travel was increased and a portion of the green fuel was shielded by brickwork from direct radiation of heat to the cool surface of the boiler. The extension furnace also permitted the use of a larger grate surface and in general allowed for greater latitude in proportioning it.

The next progressive step in furnace design was the addition of a drop nose or curtain wall located at the inboard end of furnace arch. The purpose of this drop nose was to further shield the green fuel bed from boiler tubes, provide additional incandescent surface for reflecting heat on the fuel pile and the issuing gases, and to direct the gases downward into the combustion space beyond the bridgewall. As the products of combustion from wood refuse occupy a comparatively large volume per developed B.t.u., high velocities are obtained through the furnace and it is advisable to change the direction of these gases so that they will not short-circuit into the tube surface. The drop-nose furnace, if properly designed, will accomplish this deflection and utilize to the greatest extent the combustion space, not only securing greater actual length of gas travel between fuel bed and boiler surface, but also in effect increasing the time the gases are in transit over and above that proportional to the length of travel.

There are many cases of furnaces installed in this territory where the designers have noted the excellent results obtained with the drop-nose arch but have not appreciated the full purpose of such construction as they have installed the drop nose in front of the bridgewall.

About five years ago the author considered the inclined-grate furnace used on Babcock & Wilcox boilers in the Hawaiian Islands for the purpose of burning bagasse as a possible design for the efficient combustion of hog fuel. This furnace is fitted with "step-grates," and as applied to the Babcock & Wilcox boiler is essentially as illustrated in Fig. 1.

A study of the analysis of bagasse, or sugar-cane refuse, and a comparison of it with the average sample of hog fuel show that they

each contain approximately the same number of B.t.u. per lb. dry. They both carry about the same moisture content, and the effect of the resin content of the wood refuse is about offset by the effect of the sugar remaining in the bagasse. The author felt convinced that such furnace construction, with slight modification, was adaptable to the burning of wood refuse and that its use would permit of obtaining higher capacities and better efficiencies. Early in 1922 one of the paper mills was persuaded to try out this form of furnace. Opposition from the operating engineers was encountered and the trial period was not of sufficient length to demonstrate the advantages of this form of construction. No CO_2, temperature, draft, nor efficiency determinations were made to compare it with other furnaces, and the furnace was rebuilt into one having a flat arch with a drop nose and flat horizontal grates.

In the latter part of 1922, experiments with a furnace of this construction burning waste from a wood-preparation plant were conducted at a large paper-mill plant under 350-hp. Babcock & Wilcox boilers, and comparisons made with standard Dutch-oven type of furnace. The wood waste at this plant runs from 55 to 60 per cent moisture and the results obtained from the furnace tried out indicated its worth for burning high-moisture-content fuel. The paper company at that time was installing a new boiler plant with 500-hp. units, and one of these boilers was fitted with the new type of furnace. Six months' operation showed sufficient savings from the use of this furnace design to warrant installing it on two additional boilers. Fig. 2 shows one of these furnaces now used at a papermill plant and fitted with standard grate bars set at an angle with the horizontal of approximately 45 deg.

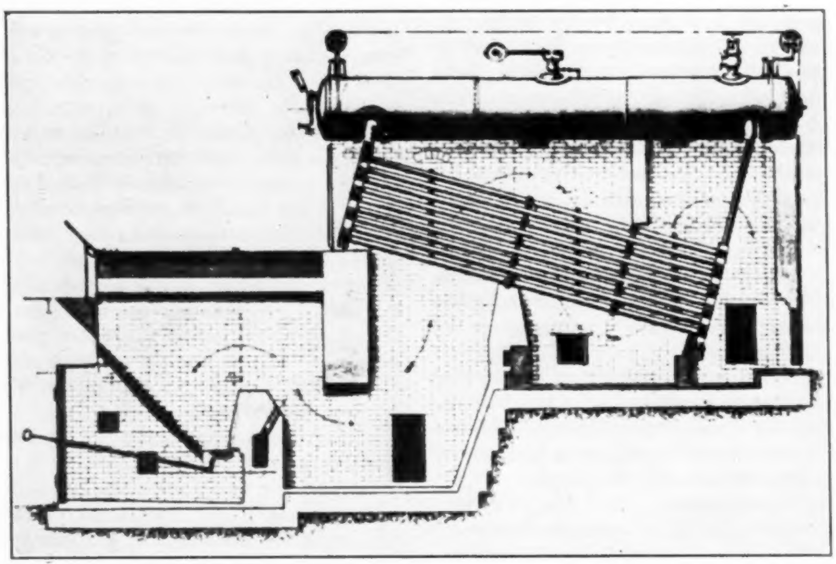

Fig. 1 Step-Grate Furnace

Fig. 3 shows an inclined furnace with step grates installed under the other boiler of the battery.

Recently two boilers fitted with these furnaces were put into successful operation at the plant of the Mountain States Power Co. at North Bend, Oregon. These furnaces have certain advantages over the flat grates.

The fuel is fed across the entire face of furnace and drops down over the grate area in a blanket of more or less uniform thickness. The ordinary method of burning fuel in conical piles on flat horizontal grates means that the central portion of the fire is too thick and the outside edges too thin for the most economical results. It also makes necessary the supplying of most of the air required for combustion by the overdraft method, due to the greater portion of the fuel on the grates being burned on the surface of the cone. In the step-grate furnace the upper portion of the fuel bed forms a distillation zone in which the volatiles and moisture content are rapidly driven off. The lower portion of the fuel bed is a mass of incandescent carbon through which the air is readily drawn, due to its open or porous nature. The process of combustion approximately consists of the uniting of air with the incandescent carbon to form the dioxide, which in turn, in passing through the remaining portion of the fuel bed, takes up carbon, to be reconverted into the monoxide. Secondary air is admitted through tuyeres in the bridgewall and unites with the monoxide gas as it leaves the incandescent fuel bed to be reconverted to the dioxide. This secondary air also unites with the volatile gases driven from the upper portion of the fuel bed and the furnace becomes in effect a combination of a gas producer and a gas-burning retort. The drop nose on the inboard end of furnace deflects these burning gases downward, allowing long gas travel before they reach the tube surface and insuring complete mixing and combustion of the gases.

With properly designed step grates there is no riddling of cinders or fuel into the ashpit. The slag which forms on the grate can be removed by slice bar between the grate openings with the plant in operation. The dump gates can then be utilized to clear the furnace of slag.

A hopper is constructed across the face of the furnace in which the fuel will form a seal preventing the admission of excess air. The secondary air supply can be separately regulated to correspond with the rate of combustion desired.

It is the belief of the author that this furnace will be used to a considerable extent in refuse burning, where efficiency and capacity are of importance.

Another high-efficiency furnace developed by the Babcock & Wilcox Company is known as the "hearth" furnace, and is illustrated in Figs. 4 and 5. As shown, these furnaces are fitted with special combustion chambers and mechanical oil burners for supplementing hog fuel with oil.

This furnace construction requires forced-draft fans and ducts and does not use any grates. The slag which accumulates can be drawn off the bottom of the furnace through the clean-out door provided.

With the "hearth" furnace favorable CO_2 percentages and efficiencies can be obtained. It offers some advantages over the step grate furnace in that there are no grates to maintain.

Many attempts have been made to burn hog fuel on mechanical stokers. The logical stoker for this purpose would be the traveling or chain grate. There are two difficulties that develop in practice in connection with such experiments. The shreds and sticks that are ever present in hog fuel interfere with uniform feeding of the fuel from the stoker hopper on to the traveling grate. The lack of uniformity in compactness with which the fuel lodges on the grate, as well as variation in its thickness, allows blowholes to develop through the fuel bed as soon as the fuel loses its volatile content. Such blowholes are responsible for excess air and low carbon dioxide content of the flue gases. Experiments tried with stokers of the underfeed type have also developed mechanical difficulties in the feeding of the fuel, due to shreds and sticks. The underfeed stokers carry a heavier fuel bed than would normally be present on the chain-grate stoker, and therefore there is less tendency to burn out holes in the thin portion of the fire.

The step-grate furnace, as earlier described, is an approximation to the overfeed stoker, depending entirely upon gravity and without agitation. Experiments have been made with agitation of fuel bed, without improvement in results, and the dry, partially consumed cinders, if agitated, have a tendency to lift from the grates.

Brickwork Difficulties

With wood refuse containing from 40 to 50 per cent of moisture there is little difficulty to be expected with brickwork attributive entirely to high temperatures, as the high moisture content precludes the possibility of obtaining excessive temperatures with this fuel. The author has made many temperature observations in various plants throughout the Northwest by means of an optical pyrometer, and seldom is 2300 deg. exceeded. The furnace temperatures are usually below 2000 deg., and frequently observations have shown as low as 1600 deg. Where mixed fuel is used or fuel entirely from dry kilns, slightly higher temperatures are obtained,

but in none of the cases observed have temperatures been indicated that would cause undue deterioration to the refractories available in this territory. However, there are kindred difficulties that develop, due to the fluxing of the refractories by the chemical effect of the ash contents and the gases given off in combustion of wood refuse. Many of the sawmills receive their logs after they have been in salt water. The wood absorbs varying percentages of moisture from the water in which it lies for indefinite periods of time, and the salt in the wood refuse (much of the wood refuse is from exterior portions of the log) causes a salt glazing or fluxing of the exposed surface of the firebrick. In addition to this, there is always present more or less lime in the ash. This comes in part from stones and shells put into the furnace with the bark. If a log has become teredo-eaten, this adds materially to the lime content of the wood refuse, as each teredo bore contains a small lining of calcium carbonate, which is calcined in the furnace. Analysis of ash has shown as high as 58 per cent calcium oxide. There have

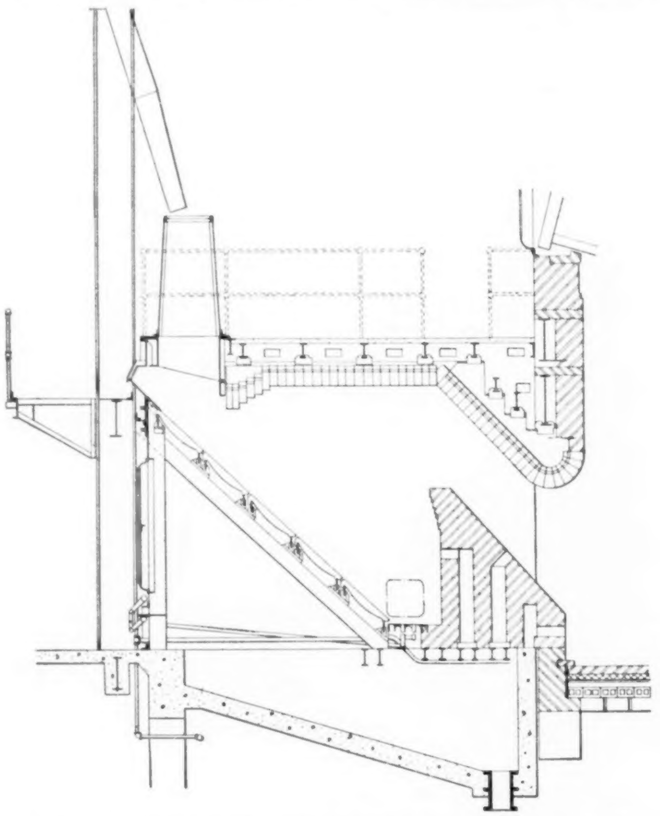

Fig. 2 Sloping-Grate Furnace with Standard Grate Bars

been very few analyses with which the author is familiar that have not shown a material percentage of iron oxide. Calcium and iron are both violent fluxes to fireclay brick made of normal mixture of oxides of aluminum and silicon. It is the combination of the chemical action of these fluxes and a medium temperature that produces the glazing and running of the furnace linings. The furnaces as a whole do not deteriorate by abrasion, but there is usually some abrasive effect along the side walls and also around the feed hole through which fuel is admitted to the furnace. This calls for frequent local repairs.

With the comparatively low temperatures obtained, spalling in wood-refuse furnaces is not marked, and the brickwork difficulties can in general be largely attributed to the chemical or fluxing action of the constituents of the ash.

Depreciation of Fuel in Storage

It is difficult to obtain accurate information regarding the depreciating effect of outside storage on hog fuel. With the wetting down from rains there is additional shrinkage due to settling. This may run from 10 to 35 per cent. The results obtained with fuel that has been stored out of doors less than six months correspond very closely per unit of volume with those obtained from fuel as it comes fresh from the mill. In other words, the deprecia-

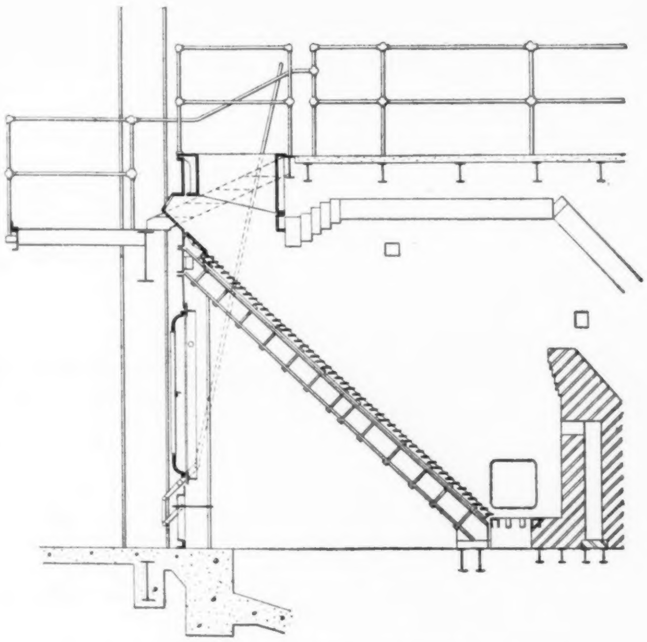

Fig. 3 Sloping-Grate Furnace with Step Grates

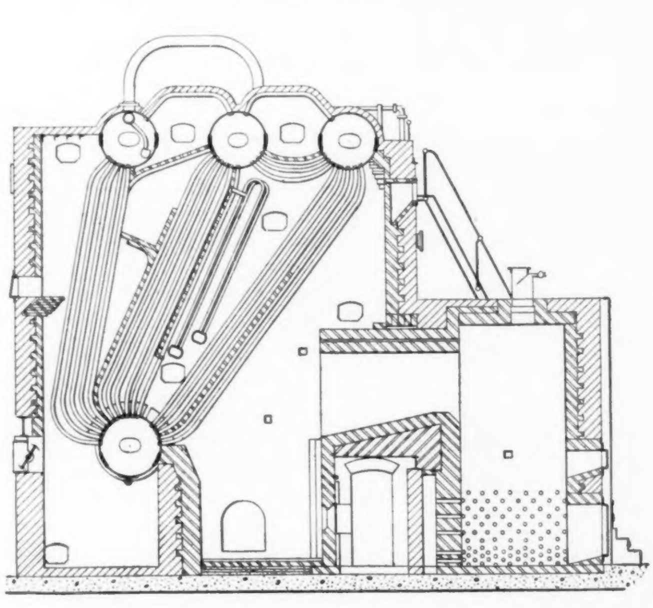

Fig. 4 Stirling Boiler Fitted with Hearth-Type Furnace Arranged for Supplementary Oil Burning with Mechanical Burners

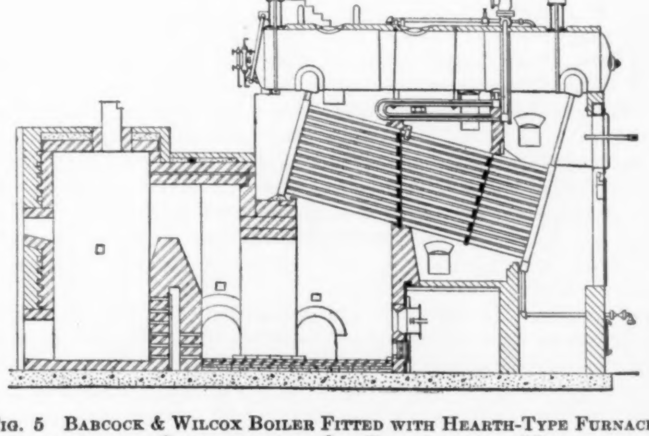

Fig. 5 Babcock & Wilcox Boiler Fitted with Hearth-Type Furnace Arranged for Supplementary Oil Burning with Mechanical Burners

tion is more or less equalized by the shrinkage in volume due to the fuel compacting in storage. As the fuel user is interested solely in the depreciation in heat value of the purchased product and not in its value per unit of measurement after storage, it is necessary to assume that fuel which has been placed in storage will be of depreciated value and that this depreciation may vary between 10 and 35 per cent. It has been claimed that little further depreciation occurs after the first six months of storage. The loss in fuel value is undoubtedly occasioned by loss of volatiles. There is evidence of fermentation going on in fuel piles, and when sorted fuel is passed through a fuel house the alcoholic odor from such fermentation is quite marked.

Future Fuel Preparation

The predrying of fuel with waste gases has been investigated with the idea that by thus disposing of the high moisture content before passing fuel to the furnace there would be more heat units available for steam production. Experiments bear out theory, however, in that there is an attendant loss of combustible volatiles with any rapid drying. No practicable means of handling this bulky product except the drying system has been developed, and until the value of the fuel has increased considerably it is doubtful whether any attempt will be made to predry the fuel commercially.

There have recently been a number of independent investigations made to determine the feasibility of destructive distillation of wood refuse and the extraction of by-products. In such an installation the recovered gas would be burned for the production of steam, and the charcoal, turpentine, and tars sold as by-products. The charcoal is fragile and finely divided and has a limited market. The wood tars can be further broken down into tar derivatives. The quantity of turpentine in woods of the Northwest is limited. Prospectuses have shown that it is entirely commercially feasible to consume wood waste profitably through destructive distillation and by-products plants, provided a market for the gas and charcoal exists. It is only a question of time before such commercial installations will be made. The capital investment will be such as to preclude such plants superseding existing steam plants for the general utilization of wood-waste products.

For the benefit of those interested in further study of this subject, the following bibliography is given.

Economic Combustion of Waste Fuels, David Moffat Myers. Technical Paper 279, Bureau of Mines.

Sawmill Refuse, Powdered Coal and Oil Fuels, Darrah Corbet. Trans., A.I.E.E. August, 1920.

Bagasse Drying, E. W. Kerr. Bulletin 128, Louisiana State University.

Tests of Boilers with Bagasse as Fuel, E. W. Kerr. Bulletin 160, Louisiana State University.

Fuel Value of Wood, H. S. Stetts and Ernest Bateman. U. S. Department of Agriculture.

Report of N. E. L. A. Prime Movers Committee, 1921.

Principles of Combustion, A. D. Pratt. Published by Babcock & Wilcox Co.

Steam, Its Generation and Use. Published by Babcock & Wilcox Co.

Boiler-Room Operation of Wood-Refuse-Fired Steam Plants

By CLAIRE C. SIMERAL,[1] PORTLAND, ORE.

There are certain operating fundamentals relative to heat balance, feedwater treatment and control, supervision, etc. common to all boiler plants regardless of the kind of fuel used, upon which the author will not endeavor to touch. The subjects covered deal directly with successful methods applied particularly to boiler plants using hog fuel, such as regulation of the fuel supply to the furnace, air and draft control, cinder elimination, clinker formation, and apparatus for handling the fuel, together with some data relative to the economic value and volume of hog fuel produced in the vicinity of Portland, Oregon.

The quality of hog fuel, both in consistency and moisture content, varies over a wide range, requiring that constant attention be given to the regulation of the fuel supply in the furnace, as different grades of fuel require changes in the volume of fuel carried in the furnace. With very coarse fuel, containing a large amount of long sticks and bark, it is necessary to maintain the fuel bed at a higher level than when the fuel is properly hogged, since the sticks and bark will not "avalanche" or flow to cover the grates as readily as the well-ground fuel, consequently a higher fuel bed must be maintained to insure that the grates are properly covered.

With a decrease of the moisture content the volume of fuel in the furnace may be increased without making necessary an increase in draft to maintain a given boiler output. With the type of furnace shown in Fig. 6, the experience of the Portland Electric Power Co. has demonstrated the necessity of so locating the fuel holes that the thickness of the fuel bed will be at least 18 in. at the bridgewall while at the front of the furnace the fuel will taper down to a "feather edge." The application of the above principles to the regulation of the amount of fuel in the furnaces tends to increase efficiency and capacity.

Continuous fuel feeding, rather than intermittent feeding, also increases the efficiency and capacity of the furnace, since with the fuel supply regulated to conform with the rate of combustion, there

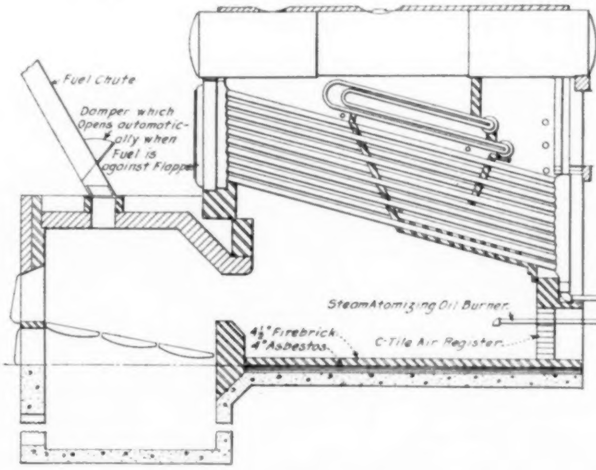

Fig. 6 Boiler Furnace for Burning Hog Fuel, Portland Electric Power Co.

results more uniformity in furnace temperatures and draft conditions, and consequently better boiler output. The advantages realized make its use quite attractive as a matter of economy, due to the direct saving in operating labor and fuel and the indirect saving in furnace maintenance.

Air and Draft Control

Hog fuel burns on the surface of the fuel bed in the furnace, which under certain conditions requires that a portion of the air for combustion be admitted at the front of the furnace above the grates. The amount of air admitted above the grates will vary from 0 to 20 per cent of the total air required for combustion, depending on the type of furnace and quality of fuel. The lower the moisture content of the fuel the higher the percentage of air admitted above the grates. The admission of air to the furnace above the grates at points other than the front of the furnaces does not give as satisfactory results for control of the combustion, and our experience has indicated that such procedure is detrimental to economy and efficiency.

Proper draft regulation is one of the prime factors in burning hog fuel successfully, as the draft must vary over a wide range to compensate for the rapid changes in the moisture content of the fuel as well as the varying depths of the fuel bed. The importance of this latter factor can readily be appreciated when it is realized that the draft resistance of the fuel bed will vary over three or four times the variation range usually encountered in a well-regulated stoker-fired coal-burning plant. Due to the necessity of properly meeting these draft conditions, automatic control of mechanical-draft equipment quite naturally is in position to play an important part in the efficient combustion of hog fuel.

In the Station L of the Portland Electric Power Company steel-plate induced-draft fans are used, driven by Corliss engines. This arrangement permits of a very satisfactory and ingenious method

[1] Asst. Supt. Steam Power Plants, Portland Electric Power Co. Assoc-Mem. A.S.M.E.

of automatic draft control, as shown in Fig. 7. A hydraulic-type pressure draft regulator is connected to the rocker arm of the fly-ball governor on the fan engine. The operation of the regulator controls, through the governor operating rods, the cut-off point of the inlet valves exactly as would be done by the governor itself. By this method the speed of the engine is entirely controlled by the hydraulic regulator, which in turn is actuated by the steam pressure at the throttle valve of the main generating units. The application of this one regulator, which controls the draft for one-third of the boilers in the station, increased the capacity of the boiler plant 10 per cent under base-load conditions and about 25 per cent for emergency calls.

Natural and induced draft are used in this station. Forced draft has been tried out, but so far without any successful results.

Cinder Elimination

Elimination of the cinders from the flue gases discharged from hog-fuel plants is required in some localities, especially where these plants are located within the corporate limits of municipalities. Both "cindervane" fans and "cyclone" dust precipitators are used for this purpose, the dust precipitators having proven more effective and reliable to date. Disposal of the soot and cinders is accomplished by sluicing them to the ash dump. Conveying them back to the furnace would naturally seem the proper procedure, but with the large amount of ash collected with the soot and cinders, rapid formation of clinkers on the grates results, which more than offsets the advantage of reclaiming the available B.t.u. in the cinders.

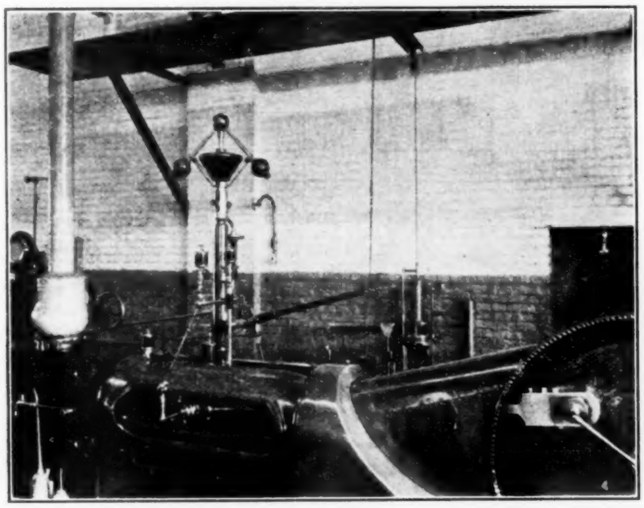

Fig. 7 Automatic Draft Control

Clinker Formation

Clinker formation on the grates depends to a large extent on the amount of sand and silt that finds its way to the furnace from the bark on the logs. Consequently the nature of the soil formation where the logs are procured as well as the method of transporting the logs has a direct bearing on the clinkers formed on the grates. The sand and silt unite with the wood ash and fuse to the grate bars. If the clinker is not immediately removed it forms a solid mass over every portion of the grate surface. The grates used in the plants of the Portland Electric Power Company are of the common rib bar type with $^5/_8$-in. air openings, and they must be thoroughly cleaned after the consumption of one unit of fuel per square foot of grate surface.

Several types of coal stokers have been tried out with hog fuel, but to date none of these have proven satisfactory on account of the excessive maintenance costs and the extreme fluctuations in the rate of combustion procured.

Fuel Handling

The means for transporting the fuel from the point of production to the boiler plant depend on the relative location of one to the other. Conveyors are used for comparatively short hauls and water and rail transportation for long hauls, the first two methods mentioned being the most economical.

Fig. 8 shows the conveyor arrangement used at Station L for loading barges. It should be noted that the short conveyor extending over the barge can be moved horizontally, which provides an equal distribution of the fuel across the barge, which is shifted parallel to the dock for distributing the fuel along its length. This particular equipment is capable of handling sixty units of fuel per hour. Removal of the fuel from the barge is accomplished with the conventional stiff-leg-derrick hoisting engine and clamshell bucket. Specially shaped teeth are bolted to the lower lips of the clamshell, which materially increases its capacity for picking up

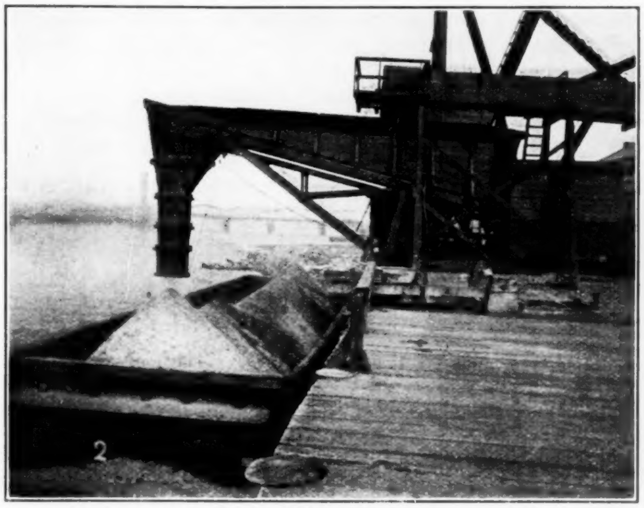

Fig. 8 Conveyor Arrangement for Loading Hog Fuel on Barges

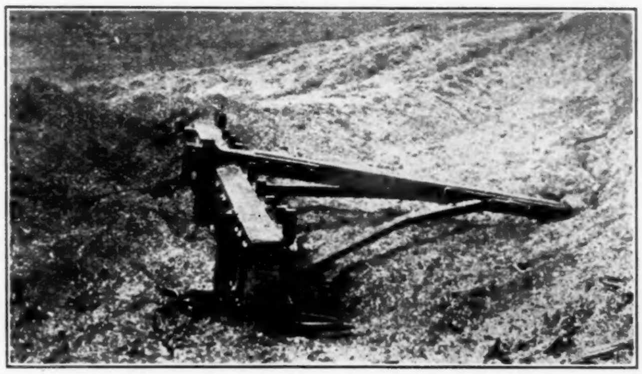

Fig. 9 Rake Used for Storing and Reclaiming Hog Fuel

and carrying the fuel. The average rate for unloading barges with a $2^1/_2$-yd. bucket is about 30 units of fuel per hour. The fuel carrying capacity of barges in use in this district varies from 100 to 250 units.

Fig. 9 shows the type of scraper or rake used for storing and reclaiming the fuel. This rake is operated with a two-drum steam- or electric-driven hoist by the use of various blocks and cables. It is designed to permit adjustment of the angle of the teeth relative to the tongue, which permits the use of the rake in any quality of fuel as well as up or down grade without becoming blocked. Raking the fresh fuel on to the storage pile requires considerably less effort than the reclaiming of the stored fuel, due to the fuel in storage settling and packing quite solidly after it has been stored a short time. The rake shown is 10 ft. wide and will handle 60 units of fuel over a distance of about 200 ft., when operated with a hoist driven by a 100-hp. variable-speed motor.

Economic Value and Volume of Production

Some of the methods or operations involved in the handling of this fuel may appear quite costly, but when one stops to consider that this fuel is a by-product of the lumber industry and that very few industrial wastes, without undergoing some intermediate manipulation, assume the economic value possessed by hog fuel, these apparent costs easily seem to be warranted.

The production of hog fuel in the Portland district during the year 1925 will amount to approximately one million units, three-fourths of which is economically available for power generation in the city of Portland. The largest consumers of hog fuel in this district are, the Portland Electric Power Company, Northwestern Electric Company, Crown Willamette Paper Company, Port of Portland, Swift and Company, Pacific Power and Light Company, U. S. Engineers, and the Portland Woolen Mills, their estimated requirements for the year 1925 ranging from 200,000 units to 1000 units in the order named.

In closing the author desires to call attention to the heat-balance data shown in Table 5 and to state that he would like to hear discussion relative to the possibility of economically reducing some of the losses indicated. He also wishes to call attention to the lack of authentic laboratory procedure for making analyses of the fuel and would like to suggest that some action be taken by the Society in establishing standards for conducting laboratory tests.

TABLE 5 HEAT BALANCE, STATION L, PORTLAND ELECTRIC POWER COMPANY

Percentage of rated capacity.	49.2	104	150	202	260	298
Test No.	24	22	23	25	26	27
Efficiency based on fuel as fired, per cent	65.0	65.6	64.6	63.0	62.9	58.1
Efficiency based on dry fuel, per cent	58.7	58.2	58.0	56.9	56.7	52.6
Loss due to heat carried away in the dry flue gases, per cent	8.5	10.1	11.3	12.7	13.5	16.5
Loss due to evaporation of moisture in fuel, per cent	10.1	11.5	11.1	10.7	10.7	10.7
Loss due to heat carried away by steam formed by the burning of hydrogen, per cent	7.6	7.8	7.9	8.3	8.5	8.9
Loss due to unconsumed hydrogen and hydrocarbons and unaccounted for, per cent	5.7	5.6	5.2	6.4	5.9	6.2
Loss due to radiation, per cent	8.3	6.0	5.4	4.0	3.1	2.5
Loss due to heating moisture in air, per cent	0.3	0.2	0.5	0.8	1.2	1.7
Loss due to carbon monoxide, per cent	0.8	0.6	0.6	0.2	0.4	0.9
Total, per cent	100.0	100.0	100.0	100.0	100.0	100.0
Moisture content, per cent	41.8	45.0	43.8	41.9	41.1	40.3
Heating value of 1 lb. dry fuel, B.t.u.	8890	8798	8971	8751	8675	8557
Heating value of 1 lb. of fuel as fired, B.t.u.	4669	4288	4519	4587	4612	4630
Flue temperature, deg. fahr.	465	471	525	560	595	660

Settings for Hog-Fuel-Burning Boilers

BY C. L. YOUNG,[1] PORTLAND, ORE.

IN THE Pacific Northwest where the lumber industry is preeminent, it follows that the utilization of mill waste is an important economic factor. The only commercial utilization of this waste to date has been its employment as a fuel. Not only are the mills burning this waste in boilers to produce the power required for their own operations, but many public utilities, on account of its low cost, have taken up its use for the production of steam in their central stations.

This mill waste in the form in which it is burned under boilers is known as "hog fuel," by which is meant the wood chips produced by putting slab wood through a machine known as the "hog." In a general sense, however, the term includes sawdust, planer dust, and shavings.

From its wide use as a fuel in the lumber regions the problem of hog-fuel combustion has assumed large proportions. That the problem has been approached more from the practical side than from the scientific angle is characteristic of the sawmill industry. However, through a long period of experimentation carried on by the sawmill operators a type of setting has been arrived at which will deliver high ratings with the accompaniment of little smoke or cinders.

Hog fuel is a very bulky and low-grade fuel. Consequently the extended furnace or Dutch-oven type of setting has been developed to provide sufficient grate area and furnace volume for burning it. The grate area for purposes of design, is generally figured at from 2.5 to 5 rated boiler hp. per sq. ft. of grate, the ratio depending on the character of the fuel.

Fig. 10 shows a hog-fuel setting applied to a 750-hp. Kidwell water-tube boiler. The grate ratio here is 1 to 2.7. This is made large on account of fuel being very wet redwood containing about 60 per cent moisture. There is a party wall which divides the Dutch oven into two parts each 8 ft. 9 in. wide. This gives additional reflected heat into the fuel bed. This is considered good practice by many where the boiler is very wide. It will be noted that there is a 2-ft. drop to the nose of the flat arch. This drop is being used very extensively. In this setting it serves a twofold purpose: (1) It deflects the gases downward, thus utilizing the lower portion of combustion chamber, and (2) breaks up and ignites the gases thrown in contact with it. The bridgewall is forward of the nose of arch. This relationship has been devised to permit the gases to be deflected downward.

The Dutch oven proper, or the portion of the setting ahead of the bridgewall, may be considered as a retort for the destructive

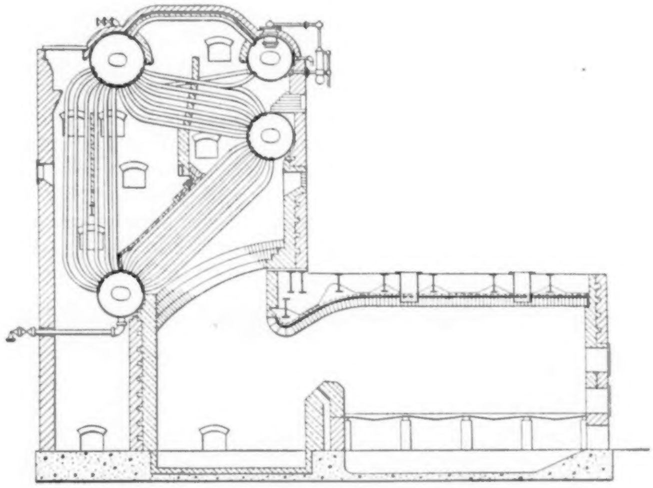

FIG. 10 SETTING FOR KIDWELL BOILER

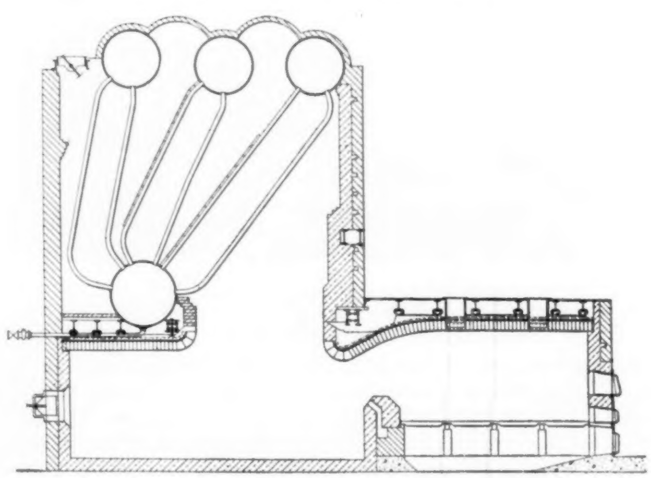

FIG. 11 SETTING FOR STIRLING BOILER

distillation of the wood. The volume over the grates is not sufficient to permit complete combustion, and it is here that the combustible gases are driven off the fuel. It follows, then, that beyond the bridgewall a combustion space must be provided for the burning of these gases and also such solids as are carried over by the draft. Secondary air is usually provided in the combustion chamber in order to complete combustion. In Fig. 10 a hollow bridgewall is shown for this purpose. Air ducts at about 12-in. centers emit air to the combustion space normal to the gas stream, the idea being that this air jetted into the gas stream will properly diffuse with the gases. In this setting a very long flame travel has been obtained, thus insuring complete combustion before gases strike the heating surface of the boiler.

Fig. 11 shows the setting for a 450-hp. Stirling-type water-tube boiler. The grate ratio here is 1 to 3.1. The Dutch-oven construction is the same as in Fig. 10. This boiler is equipped with a

[1] Johnston & Young.

flat arch under the mud drum and oil burners in the rear wall. Wet hemlock chips mixed with a little planer dust and shavings is the fuel used.

Fig. 12 shows the setting of a 643-hp. Erie City vertical water-tube boiler. The grate ratio here is 1 to 5.3. A second arch is placed above the Dutch oven in order to provide combustion space in front of the tubes. The boiler is set too low for the setting to be of the best.

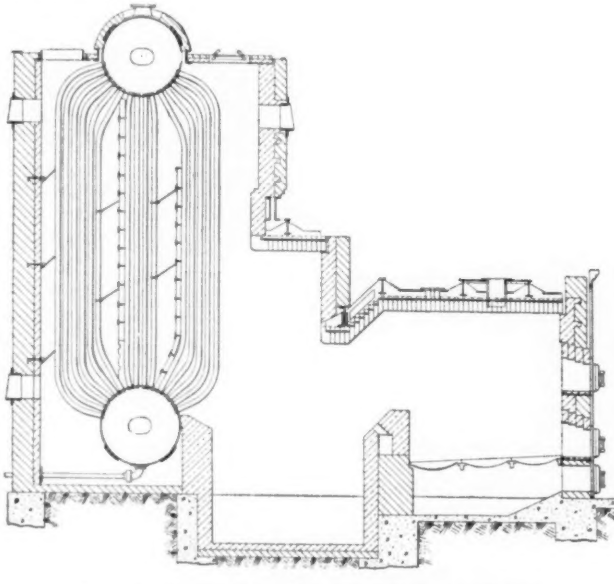

FIG. 12 SETTING FOR ERIE CITY VERTICAL BOILER

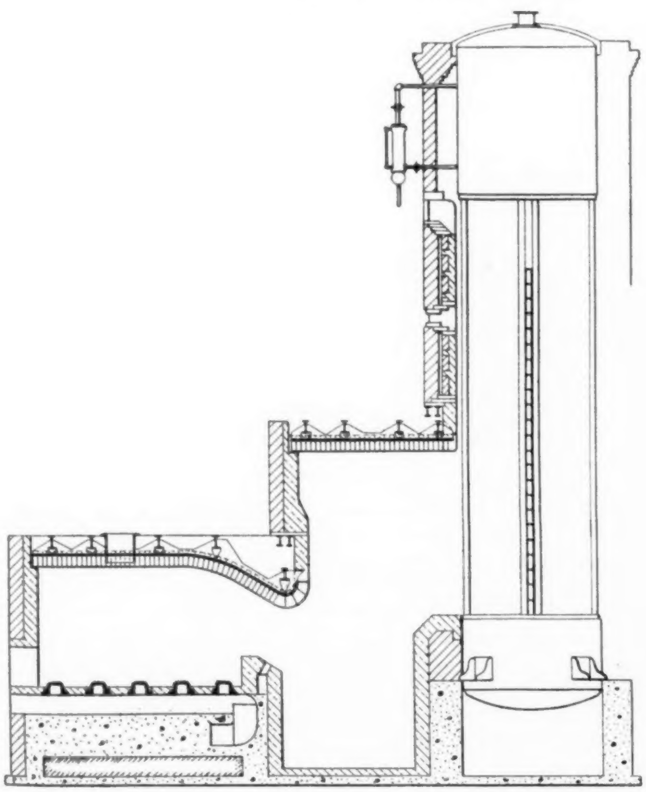

FIG. 13 SETTING FOR WICKES VERTICAL BOILER

Fig. 13 shows the setting of a 300-hp. Wickes vertical water-tube boiler. The design is similar to that of Fig. 12. The practice in the past on vertical water-tube boilers has been to bring a straight arch up to within about 12 in. of the tubes. This permitted of little combustion space and the gases were projected against the tubes unburned, resulting in poor steaming and a very dirty stack. The settings shown in Figs. 12 and 13 have very successfully reversed these results.

In Fig. 12 the absence of grates will be noted. The arrangement as shown is known as the A. I. Thomas grateless furnace. Air ducts are built in solid masonry with cast-iron air nozzles setting in cast-iron flange bases spanning the air ducts. These air ducts are covered with a brick floor into which the bases are built. The nozzles fit into the bases with a taper fit, so that when one burns out another can readily be fitted in. The air is forced into these air ducts from a fan, so an air feed through the bed of fuel is insured, since with natural draft and open stokeholes this result is not often obtained.

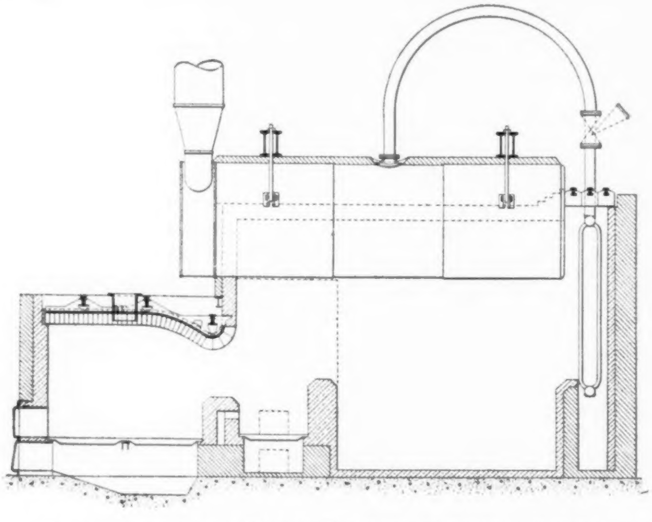

FIG. 14 SETTING FOR HORIZONTAL-RETURN TUBULAR BOILER

Fig. 14 shows an ideal setting for a 72-in. by 18-ft. horizontal-return tubular boiler. The secondary air grate as shown burns up such solids as blow over the bridgewall.

Hog-Fuel Conveyors

BY A. C. SULLIVAN,[1] PORTLAND, ORE.

HOG FUEL is one of the by-products of the lumber industry. It has been used perhaps more widely than any other so-called "waste product," and while the profit involved in the sale or use of this fuel to the lumber manufacturer is not great, still it is sufficient to warrant a more universal use than at present exists. Due to its great bulk and light weight in comparison with its low heating value, the problem of handling and transporting this fuel bears a very important part in the economy of its use.

Waste in the form of slabs, edgings, etc. is made into chips by putting such pieces through a machine commonly called a "hog." The quality of fuel delivered by these machines influences the cost and method of conveying.

The source of supply is of course the sawmill. For its own power the chips are carried usually directly from the hogging machine to the boilers or storage reserve by means of conveyors.

For power plants remote from the sawmill, hog chips are usually delivered from the sawmill conveyors by barges, although sometimes by dump-bottom railroad cars—usually of special design, by trucks, or, if the power plant be not too remote, by conveyor.

For convenience in arriving at requirements hog fuel is spoken of, handled, and figured in "units," a unit consisting of 200 cu. ft., this quantity being approximately the amount of chips resulting from hogging one cord or 128 cu. ft. of slab or cordwood.

TYPES OF CONVEYORS

Several types of conveyors lend themselves very readily to the conveying of hog fuel. The following types all have their peculiar advantages and disadvantages, but each has its place dependent upon conditions surrounding the particular problem in hand.

Belt Conveyor. Where several hundred units per day are to be conveyed over long conveyor lengths, say, of 500 ft. or more, the belt conveyor is undoubtedly the best type for the purpose. More

[1] Northwest Manager, Chain Belt Company. Mem. A.S.M.E.

material can be delivered with this type per horsepower than that of any other. The principal objection to this type for hog-fuel use is its high first cost. It cannot be used satisfactorily for fuel-conveying purposes other than delivery at one point, as trippers do not work well with hog fuel and fuel cannot readily be discharged or distributed from the belt conveyor along its length. This is due to the non-uniform and stringy characteristics of the fuel. Dependent on the quality of belt used, a belt conveyor should last for five or six years.

Wire-Rope Conveyor. The wire-rope or Jeffrey type of conveyor can be used quite successfully for the same purposes as the belt type. It cannot be operated at as high speeds, however, and has not as high a carrying capacity. The horsepower rate per unit carried is higher than that of the belt conveyor. It has an advantage over the belt type in that fuel may be distributed through openings along the length of the conveyor trough for storage purposes. Its first cost, in general, is considerably less than that of the belt conveyor. It has one rather serious disadvantage: the scraper or carrier cleats are difficult to fasten permanently to the wire rope. They frequently slip from place and out of pitch with the gap sheave or sprocket, thus causing serious delays for adjustment and repair. With proper care a cable conveyor should give good service for three years without cable replacement.

Round-Link Conveyor. The round-link wrought-iron or steel conveyor chain with carrier cleats is quite popular. Its strength, low initial cost, and fairly high carrying capacity have made its use universal. It can be used quite satisfactorily up to conveyor lengths of 350 ft. Fuel can be distributed for storage along the length of the conveyor through openings in the conveyor trough. The amount of fuel carried per horsepower is less than that of belt or Jeffrey type.

This type of conveyor has one troublesome objection. The area of wearing surface of one link on another is practically nil when the chain is new. The chain wears rather rapidly, causing an increase in pitch of the links. If this increase were uniform this annoying feature could rather easily be remedied, but unfortunately this is rarely the case and as a consequence poor sprocket action causes considerable trouble and a short life of the chain. In some cases a great deal of the trouble above referred to is caused by the selection of a chain too light for the service. The average life of a conveyor of this type is between two and three years.

Box-Link Conveyor. The box-link style of chain is used almost entirely in sawmills and sawmill power plants and is quite satisfactory for lengths of conveyors up to 250 ft. The power rate per unit of fuel carried is the highest of all the various types here considered. This is due to the friction load, as conveyors of this type are heavier per foot of chain length than any other and the fuel load added makes the total rather high. This does not seriously handicap the use of conveyors of this type as power in a sawmill is usually considered by the sawmill operator to be cheap.

Some years ago the steel box link was superior to the malleable-iron chain. At the present time, however, with the ultimate strength of malleable running from 50,000 to even 60,000 lb., the steel chain is inferior to the malleable, especially so since the steel box link has very little bearing or wearing surface on the pins or rivets.

The box-link-chain conveyor works fairly well when distribution is desired along its length. If very coarse or stringy fuel is being handled it does not work well since the fuel has to drop through the links, and chain construction limits the link pitch to a maximum of 8 in. and a width of 16 in.

The steel box-link chain should wear from two to three years without serious trouble. With proper selection the malleable chain should last from four to six years. There are installations of record that have seen twelve hours per day operation which have been running ten to twelve years and still are in operation.

Scraper-Type Conveyor. The scraper type of conveyor is probably the best for all purposes in handling hog fuel. It can be made up in many ways, but the most satisfactory one is perhaps to use a 4-in. to 6-in.-pitch steel roller chain in two strands with scraper blades carried between them at intervals of 18 to 30 in. The carrying capacity of this conveyor is high per horsepower and ranks next to that of the belt conveyor. Its initial cost is less than that of the belt conveyor, and it can be used in conveyor lengths up to 500 ft. Distribution along its length can be more satisfactorily obtained than with any other type. Its life on a 24-hour-operation basis should run from six to eight years without serious trouble or expense.

The power required for a conveyor of any type varies from that of a conveyor handling other material only in so far as the weight and characteristics of hog fuel vary from the weight and characteristics of, say, coal. There is, of course, very little gritty or other abrasive matter in hog fuel.

Construction Details

The conveyor trough and its construction should receive very careful attention. Several forms of construction are in use, all-wood, wood with sheet steel lining, all-steel construction, and composite cast iron and steel.

An all-wood construction with a hardwood bottom such as oak or iron bark and with fir sides well framed and bolted, makes a good trough where the work is light. Such a trough is inexpensive and wears well.

Most of the hog-fuel conveyors located in sawmills are of wood, well framed and jointed, with steel bottom lining, and in some cases side lining. Unless the lining is heavy it breaks loose from the bolts securing it, or the bolts get loose, thus catching on the cleats, chain, or scraper blades, causing breakage and consequent discontinuity of service and expense. Where steel lining is used in wood conveyors too much care cannot be taken to insure that the bolts or lining will not get loose.

Where large quantities of fuel are to be handled, all-steel construction should if possible be used. The first cost is of course much higher than wood or wood steel-lined, but the results obtained, if continuity of service is of value, make it in most cases the cheapest in the long run.

Probably the very best construction is a combination of steel and cast iron. The general construction does not vary materially from all-steel construction. The bottom and lower sides are made of cast iron, the upper and supporting portions of steel. This construction permits of much longer wear to both chain and conveyor trough. It minimizes the liability to breakage or discontinuity of service on account of loose protection bolts, rivets, or steel lining. If distribution openings are required, a much neater and foolproof-opening construction can be obtained. A cast-iron-bottom conveyor will last as long as the plant, and while highest in first cost it is doubtless the cheapest in the end.

In cross-section the conveyor trough is usually rectangular, the depth being approximately 0.7 of the width. Some engineers prefer a trapezoidal or pan cross-sectional form, the width at the top being greater than the bottom, the depth being 0.7 of the bottom width, and the sides being inclined from 15 to 30 deg. with the bottom. They claim greater carrying capacity for this form, but so far as can be learned this has never been supported by figures showing actual proof.

If chains are used in hog-fuel conveyors their maximum working strength should be approximately one-seventh of the ultimate strength. It is considered poor practice to operate chain conveyors very much in excess of 150 ft. per min.

Due to the non-uniformity of the material handled, care should be taken to obtain a clean discharge of one conveyor into another. Chips and stringy pieces of wood have a most uncanny faculty of hanging on to belts, chain, cleats, and scraper blades and getting into the driving machinery, causing serious trouble and annoyance. It is almost impossible at times to figure out how seemingly perfect and foolproof conveyors or conveyor systems can go wrong, but they do.

For driving conveyors electric motors, preferably of the induction type, direct connected to a reducing gear are the most desirable. A chain drive from the reduction unit to the conveyor drive-shaft makes the drive more flexible, as conveyor speeds may be readily changed should the conveyor be found running too fast or too slow.

In designing hog-fuel conveyors no set rules can be laid down. The system should be designed after careful study of the various factors entering into the problem. Generally speaking, two or possibly all the various types touched on here may be used in the system.

Engineering Standards

Evolution in Machine-Shop Practice—Standardization of Fits and Tolerances and of Screw Threads

By EARLE BUCKINGHAM,[1] HARTFORD, CONN.

ALTHOUGH we may not fully realize it, at the present time machine-shop practice is in the midst of a very remarkable and radical evolution. The march of events in this line has been so rapid that today we have the unusual opportunity of studying the course of this development in almost all of its stages.

Only a few years ago, every one who worked in a machine-shop was a machinist. He could operate any of the machines, and also do all necessary bench work. Once he got the idea of what was wanted, he could go ahead and produce it. All details of sizes, fits, and most of the general design could be safely left to his judgment. Several years were spent in training the new workers. Many rule-of-thumb practices were followed and many secrets, such as hardening or quenching mediums, cutting compounds, and browning or bluing solutions, were revealed only to a chosen few. This is what we may call the "old order."

In a modern production plant conditions are different. Instead of machinists, we find it filled with machine operators—lathe hands, milling-machine operators, drill-press hands, screw-machine operators, punch-press operators, set-up men, etc. Each workman specializes on some particular operation. The initial training he receives varies in length from a few days to a few months. The information given to him must be complete in every detail, and in addition, steps must be taken to keep a close check on all he produces. This is what we may call the "new order."

It should be evident that the kind of information required in the one type of shop is entirely different from that required in the other. It should also be evident that if the knowledge and experience that the work requires are not brought to it by the workman, they must be furnished by some one else. This last consideration is responsible for much of the standardization in mechanical parts and constructions, although of course the main reason for it lies in the economy made possible through mass production.

Standardization, in machine-shop practice, in its broadest aspect is a codification of various similar practices into one common practice for the benefit of all. It is also the pooling of information and experience to meet the needs of the growing age of specialization. To every problem there is usually more than one good solution. If several are equally good, it imposes no hardship on any one for all to concentrate on one of them as standard in order to obtain the benefits of uniformity. Because one solution has been adopted as standard, does not necessarily mean that others which have not been chosen are wrong. Usually it means that after a careful survey the one selected has been chosen because it is used by the majority and therefore has the greatest chance of universal acceptance. If this fact is kept in mind, it will answer a large number of the objections which are brought forward against the acceptance of many new standards.

Let us take as an example the recent report of the Sectional Committee on the Standardization of Plain Limit Gages dealing with tolerances and allowances for machined fits. It starts off with definitions of terms. For example, if you wish a running fit, you must provide space between the mating parts for an oil film and to insure that they will operate freely. If you desire a force fit, you must make the size of the shaft larger than the size of its mating hole. These intentional differences in the sizes of mating parts are called "allowances."

Unfortunately, very few of us can actually make parts to an absolute size. Or to put it another way, very few of us can make two similar parts with absolutely identical sizes. In actual practice we have, therefore, a variation in size to contend with. The permissible amount of such variation is defined as the "tolerance."

The definitions are followed by a selected classification of fits, eight in number, varying from a loose fit to a heavy force and shrink fit. This is followed by tables of standard allowances and tolerances for each of the selected fits.

The report is based on the practice of always having the smallest permissible hole of constant size regardless of the class of fit required. If it is to be a loose fit, the shaft member is made smaller; if a force fit, the shaft is made larger. The tolerance on the hole is plus only, while that on the shaft is minus only. This is known as the "basic-hole practice," using, in this case, the unilateral (or one-way) system of tolerances.

Although it is possible to secure the desired class of fit by making the size of either of the two mating parts larger or smaller as required, without regard to uniformity of practice, for a general engineering standard other factors than its mere ability to operate must be considered. First, the standard must represent some one good practice. Second, the practice selected should be generally the most economical to maintain. Third, the practice selected should be, if possible, the one most widely used. Fourth, the practice selected must be the one best suited to quantity production. Fifth, there should be some degree of consistency between similar standards to avoid unnecessary confusion.

The committee report meets all of these five conditions. It is a selection of one out of several practices in use. It permits of the use of standard reamers and gages on all classes of fit. For larger sizes this factor is of less importance. There would be no object, however, in adopting one practice for one series of sizes, and a radically different one for another series. A careful survey of the field indicated that the selected practice was the one most generally used.

There is an important field which this standard does not cover. This is where such material as finish-drawn shafting is used without machining, and a supplementary standard may be necessary to cover this condition. In this and similar cases it is necessary to vary the size of the hole to secure the class of fit desired. Although this field is large, it is far from being the largest, as many more shaft members are machined to suit standard holes than holes are made to suit finished shafting.

Although this standardization is for, and based on the needs of, modern production conditions, plants which have not yet been forced into these methods can also benefit by their use. The practices recommended have been adopted after considerable study and research work. The smaller shops, or the larger shops of the old school, that find it possible to use such standards will often save themselves the expense and trouble of struggling through the same course of evolution that others have gone through before them. In addition, the demands of large-production plants for large quantities of standard tools result in economies which can benefit all plants. And finally, a reasonable amount of order and uniformity in the practices followed in any plant is always an asset.

These standards are not compulsory. A successful standard must have sufficient merit in itself to secure general acceptance. When a standard is submitted to you, all that is asked is that you give it fair and impartial consideration. If this is not sufficient to secure your support, it means that either the standard is not all that it should be, or else that you have not yet reached the point where you need it, or see your need of it.

Another important standard recently adopted is the screw-thread standard. This follows in general the same outline as that given for machined fits, but in addition treats of the thread form. This standard has been widely accepted by the large-production plants, and is receiving serious attention in many other quarters.

The standard was based on actual manufacturing conditions. Each element of the thread form was considered individually and given the tolerances that the manufacturing conditions required. For example, it has always been common practice to use a larger tap drill than the theoretical tap-drill size, in order to make tapping easier and also to prevent interference on the root of the screw. On larger threaded holes, made in small quantities, where the thread was chased and not tapped, this practice was not always followed.

[1] Engineer, Pratt & Whitney Co. Assoc-Mem. A.S.M.E.

Presented at a meeting of the Metropolitan Section of The American Society of Mechanical Engineers in Newark N. J., March 25, 1925.

The conditions of chasing and tapping are different. Where taps are used, however, this practice is a necessary one. Therefore to be consistent, and also to meet the extreme cases, a clearance was provided at this point on all sizes by making the tap-drill size or bore oversize by a given amount. It is true that this practice destroys the basic form of the thread. This basic form, however, is but a starting point from which all departures are made. In actual practice it is extremely doubtful if a thread of exact basic form is ever produced.

It is well to bear in mind that the formulation of a standard is but a relatively small part of the work of standardization. It corresponds to the designing and engineering work in the plant. We all know well that there is a long road between the completion of a part or mechanism on paper and its satisfactory completion in metal.

The procedure of formulating general engineering standards is well organized. Committees for this work are organized with representation from three general groups—the manufacturers, the users, and the general public. No one group can have a majority on the committee. At the present time, however, this is the only part of the general program of engineering standardization that has been organized. One of the biggest problems in regard to this program that remains to be solved is that of transferring these paper standards into metal.

Discussion

A VERY interesting and instructive discussion of the preceding paper contributed much to the success of the meeting held by the Metropolitan Section under the auspices of the Machine Shop Practice Division at the Downtown Club, Newark, N. J., on March 25, 1925.

The meeting was preceded by a dinner, which terminated in a round-table discussion among the thirty in attendance. Following this, the meeting was called to order by Samuel H. Libby, consulting engineer for the General Electric Co., and turned over to W. F. Dixon, chairman of the executive committee of the Machine Shop Practice Division, who introduced the speaker of the evening, Earle Buckingham, engineer, of the Pratt & Whitney Co.

Following Mr. Buckingham, Chairman Dixon introduced R. A. Smith, of Smith & Serrell, Newark, who discussed the paper at some length and, mentioning various orders received by his firm for couplings, gave a concrete example of the present entire absence of standardization in shafting and keyways.

Following this, an animated and interesting discussion took place which was participated in by Messrs. J. C. Mattern, P. F. Nydegger, W. J. Peets, D. H. Chason, H. Schreck, H. J. Eberhardt, L. W. Williams, V. M. Frost, F. J. Schlink, and A. A. Adler. At the conclusion of the discussion, Chairman Dixon introduced a resolution requesting the members of the various standardization committees who were present to push forward the work in every way possible, as it was quite evident from the discussion that a very chaotic condition now existed regarding standards as applied to such products as shafting, keyways, etc.

R. A. Smith,[1] who opened the discussion, said that Mr. Buckingham's paper dealt very largely with the work of the committee, which, so far as he knew, had been based almost entirely on keeping the hole standard and in varying the shaft to get the desired fit. The class of work of which he spoke required the opposite standpoint from that taken by the committee as far as it had gone. In discussing the paper he would refer to the bores actually required in boring flexible couplings, this same practice being required of the makers of gears, clutches, etc. basing his remarks on experience and a record of over 80,000 bores varying by almost every conceivable size from $^3/_4$ in. to 18 in. In this work the bore had to fit the shaft because the shafts were almost invariably manufactured in quantity long before the bore and the corresponding fit were being considered. The shafts were those of electric motors, steam turbines, engines, pumps of all types, blowers, compressors, and other forms of direct-connected machinery. It was a fact not subject to controversy that the shaft ends on practically all such types of machines were made up to a standard practice of each individual manufacturer. These shaft ends were not subject to change, and therefore the coupling, gear, or clutch must be made to fit it with whatever type of fit was desired.

[1] Smith & Serrell, Newark, N. J.

Unfortunately while each maker made his own shafts to a standard, there was little agreement between the makers of the same type of apparatus. For example, the General Electric Co. would make a shaft 5.0035 in. and the Westinghouse Co. would make a similar shaft 5.000 in. Both of these companies would grind the shaft to a very close limit, usually between the size mentioned and 0.0005 in. smaller. On the other hand, such a representative company as the De La Vergne Machine Co. would turn their shafts between the limits of exact nominal size and 0.002 in. smaller. No criticism of the practice of any of these companies was intended; the only point was that they might just as well get together and all do the same thing, or all be on the same side of the nominal dimension, and then it would eliminate the great variety of bores required from the manufacturer of the coupling, gear, or clutch.

In order to present some concrete facts Mr. Smith had gone over several hundred bores recently required and tabulated them. These bores he had classified into fourteen groups, and the inconsistency of this multitude of requirements was shown by the fact that on the same coupling two different styles of bores were often required. Even though only about 200 orders were analyzed, the listing would show that in many groups certain items called for a bore on the other end of the coupling belonging to a different group.

Group No.	Requirements	Remarks
1	Exact standard diameter[1]—no tolerance	Out of 8 items 4 called for a different bore on the other end
2	Standard diameter $+0.000$ -0.001	Out of 6 items 2 called for a different bore on the other end
3	Standard diameter $+0.000$ -0.002	
4	Standard diameter $+0.001$ -0.000	Out of 4 items 2 called for a different bore on the other end
5	Standard diameter $+0.002$ -0.000	
6	Standard diameter ± 0.001	Out of 3 items 1 called for a different bore on the other end
7	Standard diameter ± 0.002	
8	Standard diameter—press fit or force fit	Out of 7 items 1 called for a different bore on the other end
9	Non-standard diameter—no tolerance	Out of 4 items 1 called for a different bore on the other end
10	Non-standard diameter $+0.000$ -0.001	Out of 4 items 2 called for a different bore on the other end
11	Non-standard diameter $+0.001$ -0.000	
12	Non-standard diameter ± 0.001	
13	Bore between certain limits	Often the difference between the limits on one end will be, for example, 0.001 in., whereas on the other end it will be, for example, 0.002 in.
14	Pin gage—no tolerance	The single item in this group called for a different bore on the other end of the coupling

[1] "Standard diameter" means by steps of $^1/_{64}$ in.

The making of a variety of bores commercially, Mr. Smith said, required their boring in a turret lathe or boring mill, and it was not usually practical to grind the bores with such a great variation in size as required. The practical limit of accuracy even with very careful work was to bore within a tolerance of 0.001 in. Whenever any one asked for closer than this, the closer limit was refused and he was told that a tolerance of 0.001 in. was all that was guaranteed. Whenever a bore was called for without a tolerance specified, the following factory tolerances were automatically applied:

Nominal Bore. Up to 1200 r.p.m. for medium and light duty where the nominal shaft diameter was given as $2^{13}/_{16}$ in., bore from 0.0005 in. to 0.001 in. larger. Bore would be a sliding fit on the $2^{13}/_{16}$-in. shaft and would require set screws.

Micrometer Bore (or bore to gage). Where specified for medium or heavy-duty work; also where it might be desired to install in field, bore from 0.000 in. to 0.001 in. less than (2.8125 in.) specified. Plug gage would not enter bore. A pin gage would enter bore and be a tight fit. Bore would be a snug fit or a light press fit on (2.8125 in.) shaft, depending upon smoothness of shaft turning at bore. Set screws optional.

Press Fit. Bore from 0.0015 in. to 0.0025 in. less than micrometer size of shaft or gage (if gage was an exact measure of the shaft diameter) depending upon shaft size. No set screws.

Mr. Smith said that he would like to see the adoption of some standard size of shaft according to which the various makers of direct-connected machinery would turn or grind the ends of their shafts. Such a procedure would reduce the number of gages required and would very much simplify the problem of shaft and bore specification. It would not cost any more than the present practice except for the small cost of changing the gages the first time over to the adopted standard. If the shafts were so standardized it would then be very much easier to do the same thing on bores of the coupling, gear, and clutch members. The bores would fall into a comparatively few classes, probably not over three, and the problem of gaging such bores would therefore be much simplified.

Referring to standards for keys and keyways, Mr. Smith said he understood that the key committee had not yet published its solution—if it had one. Generally speaking, keyways in shafts were milled and the width of the keyway was therefore dependent on the width of the milling cutter. The keys in the coupling, gear, or clutch were generally made on a special keyseating machine which essentially was a slotter with a formed tool having a definite width. The keyway width was therefore a function of the tool width and these tool widths were usually within two to three thousandths over the nominal size, with a reduction, due to wear and to regrinding, down to two or three thousandths undersize. It was not feasible in commercial work to spoil keyway cutters to meet some one's special idea of a preferred keyway width, and the keyways should therefore be cut to the width produced by keyway cutters in the market. If any standards of key widths and keyway widths were determined, they should take this point into consideration. Some few companies had specified keyway tolerances and one particular company of large size now specified the keyway width as 0.002 in. less than nominal and in addition gave it a tolerance of ± 0.001. For example, the keyway width was called for as 0.498 ± 0.001, or 0.623 ± 0.001. Such special requirements should be refused as, except in that company's own shops, there were no other similar requirements and certainly no one wanted to add to the special tools required. It seemed to Mr. Smith that the demand for such special keyway widths was unnecessary because to get a good fit practically every key of ordinary style had to be hand-fitted by filing or grinding.

Mr. Smith therefore recommended to the committee that it should proceed to establish preferred standard sizes of shafts and bores which would meet the direct-connected-machinery problem, because its work up to the present, so far as he knew, did not enter this field with which every machinery user was in contact. He stated that his company had a mass of tabulated material covering many thousands of bores and keyways and that this information was available on request.

Whenever such a standard was set up he hoped that the standard would be of such a form that it would be readily adopted by machinery manufacturers, and that steps would be taken to see that it was adopted rather than to have it as a superimposed additional standard on top of all the variations already in effect.

J. C. Mattern,[1] referring to a statement made by Mr. Smith that keyway cutters were made 0.001 in. above standard size, raised the point that the great bulk of cold-rolled key stock, as purchased in the open market, usually came from 0.001 in. to 0.002 in. below standard size. This being so, a keyway cut 0.001 in. above standard size must invariably fail of assuring a snug fit sidewise.

Mr. Mattern contended that all keyways should but cut from 0.002 in. to 0.004 in. below standard size, which would permit of securing close fits with keys made from regular key stock.

In connection with Mr. Buckingham's statement that definite screw-thread standards had been established, Mr. Mattern inquired whether these would make it possible, in assembling all kinds of machinery, to set allowances for each different class of fits. Mr. Buckingham replied that each standard was divided into five different classes—one of which would be sure to meet practically any condition which could arise in machine building of whatever kind.

[1] Equipment Engineer, Singer Mfg. Co., Elizabethport, N. J. Mem. A.S.M.E.

P. F. Nydegger[1] asked Mr. Buckingham whether the tolerances established between 1914 and 1920 by the German, French, Swiss, and Swedish engineering societies of the various fits as well as for the current sizes had been consulted during the formulation of the A.S.M.E. limits and standards. He thought that as the European standards had been already established for a number of years, it would be desirable to compare those that had proved satisfactory in practice with our own A.S.M.E. limits and standards.

The author answered that European standards were on file at the American Engineering Standards Committee and had been consulted by the sectional committee. That it was interesting to note that the German fits, for example, were in general one degree closer than ours, and that this probably meant that the German manufacturers relied more than Americans on an ultimate hand scraping of mating surfaces if the allowance proved to be insufficient in actual practice.

Mr. Nydegger stated also that, as no mention was made in the paper or in the discussion of the finish of either holes or shafts, he thought it necessary to point out that the use of lapping methods for cylinder wristpins, sewing-machine shafts, and pins after grinding, and also the introduction of diamond finishing tools to get highly finished bearings in both ferrous and non-ferrous metals, necessitated different limits from those generally in use to allow for an oil film of a needed thickness to insure long service.

Before the development of the newer methods of finishing bearings by the process of lapping or with diamond cutting and burnishing tools, it had been necessary to resort to the slow method of running-in the parts so as to smooth down the rough high spots in assembled units and obtain the desired finish of the bearings.

With the newer method of lapping and diamond reaming as the *last operation of machining*, a more highly finished surface was produced, greatly reducing the time formerly consumed in running-in, as, due to the fact that all high and rough spots were now eliminated, the running-in operation was either unnecessary or greatly reduced in time.

H. Schreck[2] made a few suggestions in regard to the standards of fits and gages as proposed by the Committee on Gages. These were:

1 The subdivision or number of fits was not sufficient to meet the requirements of the shop,

2 The allowance between tightest and loosest fit was too great. For comparison he had plotted the four following systems:

1 The proposed A.S.M.E. standards
2 The Newall Engineering Co.'s standards
3 The German (V D I) standards
4 Standards of an American Diesel-engine works.

Comparing, for instance, a running fit on a 2-in. and a 5-in. nominal size, the specifications for tightest and loosest fits would be as shown in Table 1.

TABLE 1

	Tightest fit		Loosest fit	
	2 in.	5 in.	2 in.	5 in.
1 A.S.M.E. (proposed)........	0.0014	0.0026	0.0034	0.0054
2 Newall.....................	0.0009	0.0015	0.0032	0.0050
3 German (V D I)............	0.0011	0.00145	0.0032	0.0043
4 An Am. Diesel-engine works.	0.0001	0	0.0025	0.0038

The limit-gage system No. 4 had been established by Mr. Schreck some years ago, while he was working as chief engineer with a Diesel-engine concern in the Middle West. It had been copied from the licenser in Europe and was very much closer than system No. 3. It might be noticed that it was based on a "standard shaft," and that the other three systems followed the "standard hole" practice.

Mr. Schreck had also recently had the opportunity, as works manager of a Diesel-engine manufacturer, to install a limit-gage

[1] Supt., Singer Mfg. Co., Elizabethport, N. J. Mem. A.S.M.E.

[2] In Charge of Design, Combustion Utilities Corpn., New York, N. Y. Mem. A.S.M.E.

system in which the gages had been made a little closer than No. 3, and yet not too close to increase cost of manufacture. The system had proved a great success in the shop as well as in the working of the engine, contrary to what might be inferred from Mr. Buckingham's remark on the A.S.M.E. fits as compared to German standards. Notwithstanding Mr. Buckingham's assertions based on his experience in machine-tool work, Mr. Schreck desired to point out and to suggest that the proposed limits be very carefully checked for the use on reciprocating machinery, which covered such a large range of our engineering work.

Mr. Buckingham, in reply, said that Mr. Schreck had pointed out the very pertinent difference between fits required for reciprocating members such as crankpins and ordinary revolving shafts. Fits for reciprocating members should be held much tighter than those for revolving shafts. The class 3, Medium Fit, as proposed in the first method of Table 1, was too loose for this purpose. The class 4, Snug Fit, which gave a tightest fit of zero and a loosest fit of 0.0013 on a 2-in. size, and a tightest fit of zero and a loosest fit of 0.0017 on a 5-in. size, would be a better selection for this purpose. This would give only about half the manufacturing variation that Mr. Schreck had successfully used, as shown in the fourth method of Table 1, and might thus be unduly expensive in production. It was possible that an additional classification should be added to the proposed specification to take care of such fits for reciprocating members. The previous remarks in regard to closeness of fits and hand scraping applied only to fits on rotating members, where the general tendency existed of making them too tight, and freeing them after assembly.

H. J. Eberhardt[1] took part in the discussion which developed regarding the best practice in the use of master gages and the tolerances allowed between the gages used by the operator of the machine and the master gages kept in the tool room.

Referring to the work of the shafting committee under the American Engineering Standard Committee, Mr. Eberhardt suggested that as soon as the present work of this committee, which was now being considered on transmission shafting, was finished, it should be broadened to also include such shafting as came in the machine-tool group, and then the higher-speed group of automatic machinery and aeronautic engines.

W. J. Peets,[2] replying to a question by Mr. Eberhardt as to the proper method of keeping a plug gage used by the operator in absolute conformity with another gage held in the tool crib, and whether the gage on the shop floor should be to a slightly closer limit than this test gage, expressed the opinion that the best practice was to give the operator a gage of exactly the same limits as were used for final inspection, so that he would have the full benefit of the tolerances allowed. Also, that it was well to give the operator two plug gages—one to be used regularly on the work, and the other held in reserve for gaging holes coming very close to the lower limit and which might pass a somewhat worn gage.

D. H. Chason[3] inquired as to whether the practice, originated during the war, of having gage makers' limits shown on parts drawings was still widely followed. He also outlined the practice being used in the most modern shops today and which had been in use for some time.

For purposes of economy in making gages of, for instance, a total limit of ten thousandths (0.010 in.), the gage maker was given a specific tolerance known as the "gage maker's limit." Supposing then that a gage of the "go no go" plug type was required, on which the "go" diameter was 0.495 in. and the "no go" 0.505 in.; the most suitable tolerance to allow would be plus 0.0003 in. and minus nothing on the "go" size, and plus nothing and minus 0.0003 in. on the "no go" size. If then the gage maker should take the full limit on one or both diameters, the proper gaging of the work to be handled would not be affected.

Gage manufacture could well cost 50 per cent more than otherwise in the absence of a "gage maker's limit" on the drawings. For instance, when a gage maker was lapping a plug to a flat figure (i.e., without such a limit) and the lapping had come to within 0.0001 in. of the specified size, he must proceed with care not to remove more than 0.0001 in. from the gage. Further, the gage had a tendency to warm up in the lapping process, with consequent liability of a false reading on the gage maker's micrometer.

Although a 0.0001-in. limit seemed very small, it was a very important factor in facilitating the gage maker's work, and therefore in reducing gage costs. In many shops which followed this system, comparatively inexperienced operators were able to make the gages required.

Louis W. Williams,[1] in reply to the Chairman's request for information as to the work of the Committee on the Standardization of Shafting and in reply to one of the statements made during the discussion of the paper that standards were too often recommended which were not adaptable to commercial practice, said that the Committee on the Standardization of Shafting and its sub-committees on keys, tolerances, etc. had been working for several years to prevent this condition. The Committee had consulted with hundreds of users and a large number of manufacturers of shafting, keys, transmission appliances, and cold-finished steels. It had obtained the viewpoints of users and makers and wherever possible reconciled them. When this had not been possible, the Committee had recommended standards which would conform to general practice as shown by a large majority of the hundreds of letters received in reply to its several questionnaires.

Individual requests to alter the Committee's standards as recommended to agree with the practice in some particular shop had had the Committee's serious consideration. When these requests had conflicted with the practice generally in use, it had been forced to decide in favor of the large majority of actual users.

The Committee regretted that a list of shafting sizes agreeing with a preferred-number series could not have been adopted as a single standard for both transmission and machinery shafting, but such a standard would not have appealed to the man in the shop as it would not have conformed to equipment now in use for which repair parts were carried, nor with shafting practice in general as shown by data from makers of transmission equipment and machinery of all kinds.

The Committee's standards had been recommended mainly for the purpose of reducing the number of sizes and of establishing commercial tolerances. This should help the machine manufacturer, shafting maker, and distributor materially by lowering the list of sizes to be stocked.

A request for further elimination of some of the key sizes recommended for standard keys had been received by the Committee, the writer saying that he had not been informed of the Committee's work as it progressed. C. B. LePage, Secretary of the Committee had sent him a list of articles which had appeared in Mechanical Engineering at various times, which convinced the writer that he had not been reading the Society's publications very closely.

Regarding the distribution of information as to the Society's standards and useful data to the members interested, such information, when printed in Mechanical Engineering, was apt to be casually noted but would not be at hand when actually needed unless one had a complete clipping system. If standards were either printed as data sheets, as done by other societies, or in Mechanical Engineering in a uniform size with holes indicated for binders in the way that some of the newspaper supplements furnished radio data, it would undoubtedly be of great service. Much valuable information was being developed by the A.S.M.E. but it was not being supplied to the individual members in its most useful form.

V. M. Frost,[2] commenting upon a question raised as to how a standard having been adopted by the Society could be put into use, stressed the point that when the Society adopted a standard which was agreed to be reasonably correct, the only thing necessary to put it into force for application was to "sell" the idea to the users of the product and they would do the rest by clauses in their contracts and specifications requiring that the material furnished comply with the given standard.

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[2] Engr. in charge of Factory Methods, Singer Mfg. Co., Elizabethport, N. J. Jun. A.S.M.E.

[3] Methods and Equipment Engr., Singer Mfg. Co., Elizabethport, N. J. Assoc-Mem. A.S.M.E.

[1] Secy., Cauldwell-Wingate Co., New York, N. Y. Assoc. A.S.M.E.

[2] Asst. to Gen. Supt. of Generation, Public Service Electric Co., Newark, N. J. Mem. A.S.M.E.

F. J. Schlink[1] called attention to the universal use by the foreign bodies which had issued standards on gaging, of diagrams or charts intended to give a complete and comprehensive picture of the whole gaging scheme at a glance. The British and German standards, which were typical of a large group of European standards for limit gaging, were exhibited by Mr. Schlink to show the charts which they contained, from which the general plan of the tolerances and allowances and their magnitudes could be seen in relation to each other. He suggested that the American report should ultimately be revised to include such a presentation of the data which, on account of the complexity of the subject and the numerous grades of fit, would otherwise not be sufficiently clear, as a coördinated plan, to a person not already expert in the gaging field.

Referring to Mr. Smith's discussion, Mr. Schlink pointed out the importance of an accurate numerical study of the cost of non-standard production. The numerous and diverse methods of specifying shafts and holes which were essentially the same or intended for similar purposes, involving actual differences in dimensions which were often minute and unimportant, certainly carried unnecessary expense in the shop, particularly in the general manufacturing or jobbing shop, which might receive its orders and specifications from the most diverse sources. Such a shop, if provided with an accurate cost system, could work out the difference in cost produced by the small deviations from standard sizes and limits, and a study of this kind would be of the utmost importance in bringing about an appreciation of the value of standardization in this and related fields, and would almost inevitably put the matter of charges for work on a basis where the purchaser would quickly resort to standard sizes and types whenever they would equally well serve his purpose.

Carl J. Oxford, in a paper on standardization of small tools published in the November, 1922, issue of MECHANICAL ENGINEERING, had shown how the manufacturing cost of certain twist drills was about 500 per cent higher than in the case of the standard product of the same design throughout, except for its length. A few definite figures of this character would make a very great difference in the willingness of engineers to adhere to the national standards, and Mr. Schlink expressed the hope that some member of the Society might give the public the benefit of such a study.

Alphonse A. Adler[1] told how the members of the Committee on the Standardization of Shafting were selected and how the standards were formulated.

The Committee members, said Dr. Adler, were selected from the membership who by their interest and knowledge were able to contribute to the weight of the opinion formed by the Committee as a whole. All differences of opinion as far as possible were smoothed out in the meeting and the problem was clearly formulated. The Committee then sent out questionnaires to the interested parties so that they would know in question form exactly what answers were desired. These answers were tabulated and discrepancies corrected by such means as seemed desirable for the case in hand. This process was continued until substantial agreement was effected.

As far as he knew, the Committee always tried to avoid raising the price of the product for those whose requirements did not need the accuracy called for by the close tolerance. It also tried to pass the expense of close tolerance or special product to those who by their specification were willing to pay for it.

In general the Committee, on which he had the honor to serve, believed that no standard would remain standard unless there was a preponderance of manufacturers, designers, and users behind it. No single party was in a position to get the kind of perspective obtainable by the Committee unless he combed the field in the same way that the Committee in charge had. His experience on the Committee had made him feel that it was as broad-minded an undertaking as he had ever had the pleasure of being connected with.

[1] Asst. Secy., American Engineering Standards Committee, New York, N. Y. Mem. A.S.M.E.

[1] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

Principles of Metallurgy of Ferrous Metals for Mechanical Engineers[2]

III—Determination of The Properties of Metals

BY LEON CAMMEN,[3] NEW YORK, N. Y.

IT IS important for the mechanical engineer to understand how the properties of metals are determined. To do this numerous tests have been developed, but with the exception of some very unusual cases, it is by no means necessary to put a metal through all the tests that are to be described. Thus, there will be no sense in testing a rail for resistance to stresses at high temperatures, because a rail in service is not exposed to high temperatures.

The tests to which metals are subjected may be divided into the following classes: Physical tests; chemical analysis; determination of structure by microscope, reflection photography, and X-ray photography; magnetic analysis; analysis by sound; determination of corrosion resistance; determination of erosion resistance; determination of electrical properties; spectroscopic analysis; determination of physical constants; tests for machinability, cold and hot working, and forging; determination for stability, physically and chemically.

PHYSICAL TESTS

Some of these are so familiar to mechanical engineers that they need be mentioned by name only; concerning others a few words may be added. Tensile tests, compression tests, bending tests, impact tests on plain and notched specimens, and alternating-stress tests in metallurgical work do not differ in any way from those used in mechanical engineering, except that, especially of late, metals have been tested for their physical properties not only at room temperature but also at temperatures ranging as high as 2200 deg. fahr.

As regards hardness, it is important to understand that the various tests such as the scratch, Brinell, Shore, Rockwell, and Herbert do not all indicate the same property of the material. As has been already stated in another paper in MECHANICAL ENGINEERING,[11] "It would appear that there are five distinct kinds of hardness, of which two are complex and three simple: (1) *Compound indentation hardness,* measured by the pendulum time test, a composite quality comprising (*a*) *plastic indentation hardness,* measured by the Brinell test, and (*b*) *elastic indentation hardness,* measured by the pendulum time test on glass, rubber, and the hardest steels, but otherwise not yet isolated; and (2) *work hardness,* or resistance to working with a tool, measured by the pendulum scale test, a composite quality comprising *hardness indentation* as above and *flow hardness,* or resistance to flow, measured by the pendulum scale time ratio."

Furthermore, in special reference to plastic indentation hardness, the Brinell test, which uses a ball, indicates the *average* hardness over a comparatively extensive area. The Rockwell test with its small diamond point is capable of measuring hardness over a

[2] Third of a series of articles discussing the underlying physical and chemical processes involved in the metallurgy of iron and steel. The first, dealing with the physico-chemical properties of iron alloys, appeared in the May issue, p. 339, and the second, on the crystalline structure of ferrous metals, in the June issue, p. 479.

[3] Associate Editor, MECHANICAL ENGINEERING.

very much smaller area, often equivalent to that of one crystallite or even a part of a crystallite and is thus capable of giving a reading more representative of the actual conditions than the Brinell reading integrated over a much larger area.

It has been found that alternating-stress tests are apt to give misleading results unless certain precautions are taken to obtain a correct application of load. This has been done, among other methods, by inserting a thin cardboard cylinder between the test piece and the inner race of the ball bearing through which the load is transmitted, the purpose of the cardboard cylinder being to assist in uniformly distributing the load.

While there is undoubtedly a close relation between the physical properties of metals and their constitution, it has not been sufficiently established so that one can be guided by any definite rule. Generally brittleness increases, other conditions being constant, with the size of the grain, but it is possible for an alloy consisting of small grains to be more fragile than one consisting of larger grains, given a certain orientation of the grains (cp. Chapter II on Crystalline Structure of Metals). It is also possible, to a certain extent, to predict the mechanical properties of metals from their constituents, but here also our knowledge has not yet reached the stage where such predictions can be relied upon for practical purposes, so that the test is the final determination of the mechanical properties of a metal.

It is important to remember that the results of all tests depend on the extent to which the piece tested is representative of the material the qualities of which it is desired to know. Thus, for example, when a casting is made and a test bar cast from the same metal and the latter on test shows excellent properties, this does not mean that the casting will stand up well in service, because the pattern may have been so improperly designed as to produce thin sections between heavy sections, with the result that contraction stresses will bring about the rupture of the former. A good deal depends also on the type of test bar and method of casting it. For certain cases such organizations as The American Society for Testing Materials have adopted rules as to the methods of casting standard test bars. Where such rules have not been adopted an endeavor should be made to have the test bar cast in substantially the same manner as the casting, and, for example, such practice should be avoided as having the test bar cast in a metal mold where the actual casting is poured in green sand.

Chemical Analysis

The purpose of the chemical analysis is to determine whether certain useful constituents are present in sufficient quantities and certain undesirable elements are kept below the specified limit. The important constituents in ordinary steel are carbon, which, as has been stated above, vitally determines all the properties of the metal; sulphur and phosphorus, which often give it undesirable properties; and silicon and manganese, the influence of which will be discussed later, and which may be considered desirable or harmful within certain limits and less so within other limits. In alloy steels the alloying elements must be present within certain limits, and it is up to the analysis to establish it. It is well to state in this connection that on the whole it is not desirable to specify both the chemical analysis and the physical properties of a metal.

It is often impossible, especially on account of the practice followed in a given foundry or steel mill, to produce a metal of a certain chemical analysis which at the same time will have certain physical properties. Therefore, if it is the analysis which is important, only that should be specified, and in some way proper inspection should be provided to see that metal of the desired analysis is melted and handled properly. If it is the physical properties which are desired, they should be specified and a certain leeway given in the matter of the analysis to permit the foundry or steel mill to use its own judgment in producing a metal endowed with these properties. To specify both is like telling a man to take only so many steps per minute and yet cover a certain distance in an hour. This would be all right if all men had legs of the same length and their steps were of the same spacing. As a matter of fact, steels made from Swedish ore and Ruhr coke, for some reason or other, have physical properties (with the same treatment) not at all like those made from Mesabi ores and Connellsville coke and apparently of the same composition.

In specifying the analysis of a steel, it is important to determine first of all the purpose for which the metal is to be used and the processes by which it is to be manufactured. For example, in steel used for rolling structural shapes, a small amount of oxidation, provided it does not result in what is known as "dirty" steel, is fairly harmless. If, however, the steel is to be case-hardened, the same amount of oxidation may prove to be very objectionable.

This example, it may be noted, is of interest in that it shows how at times the problem of analysis is handled by the steel man. The usual way is of course by direct determination. Once in a while conditions arise, however, when roundabout ways appear to be more effective. Such, for example, is the case of steel for roller-bearing races. This steel has to be case-hardened, and the presence of oxides in the metal would interfere with the case-hardening. Now while it may be possible to discover the presence of oxides in steel by means of chemical analysis, there is no rapid method of analysis available. Because of this, the Timken Roller Bearing Company uses a somewhat roundabout method and specifies 0.5 per cent chromium in its steel, the idea being that if oxides of iron were present in the steel there would not be any chromium in it, as the latter metal oxidizes long before iron does. Here, therefore, by determining the amount of chromium present, a conclusion is reached as to the presence, or rather the absence, of oxides of iron. In other instances, however, the practice of using deoxidizers or indicators is objectionable and therefore prohibited. Thus rail specifications usually provide that no aluminum shall be used as a deoxidizer, because of the fear that heavily oxidized metal would be produced in the furnace and that reliance would be placed for its deoxidation on the use of aluminum, a process not really sufficiently certain to be relied upon in the case of a product, such as rails, where reliability and safety are paramount.

As regards phosphorus, there is fair agreement that it should be kept below 0.05 per cent, and even lower limits are specified where articles are subjected to heavy alternating stresses and the danger of cold-shortness is particularly prominent. On the other hand there is much less unanimity as regards the upper limit for sulphur. Some ten years ago 0.05 per cent was considered the highest limit permissible for all products subject to stresses. Of late, however, a closer study of the influence of sulphur has been made and there have been apparently well supported claims that higher limits of sulphur may be permissible under certain conditions.

As a rule, no single set of tests will tell the whole story. Thus excessive brittleness as discovered by the impact test or alternating-stress test may be due to an accidental defect in the test piece, such as a bit of slag inclusion, of which the article itself may be free. A sulphur content in excess of the supposed permissible higher limit may under certain conditions prove to be beneficial rather than harmful, but when excessive brittleness is found in combination with excessive sulphur content (this is, however, cited merely as an illustration), it is well to consider immediately whether lowering the sulphur limit would not prove to be of advantage. On the other hand, when unusually high physical properties are discovered with an apparently conventional analysis, it may be well to subject the test piece, especially if made from materials of unusual occurrence, to a complete analysis, that is, an analysis that will show constituents totaling 100 per cent, in order to discover if there is not some constituent present that would account for the unusually excellent properties.

It is well to understand that in the first place chemical analysis of the metal does not always disclose all that goes into the making of the metal or all that affects its properties, and second, that unless one knows what to look for in a chemical analysis it is very easy to fail to discover certain constituents even when present. This is due, first, to the fact that certain alloying elements affect the structure of steel while present in molten metal, and then pass into slag so that they are not present in the cast metal. Such an element is titanium, titanium steel so-called—and quite legitimately—often showing no presence of titanium on chemical analysis. Other alloying elements are added in such minute quantities that they would not be discovered by ordinary analysis unless their presence was suspected and certain reagents used. Such an element is vanadium, which is added in quantities of only 0.1 per cent, and the magnesium or cerium used as a deoxidizer in some special steels is added likewise in quantities of 0.1 per cent or less. These deoxidizers pass into

the slag so completely that their presence is not discoverable in the cast metal. Of late an attempt has been made to introduce certain organic materials into molten steel, and it is claimed that the resulting metal is improved thereby. Of course, such organic materials would undergo under the action of heat at the temperatures of molten steel such a thorough transformation as to make their presence absolutely undiscoverable in the final metal.

The methods of making the analyses themselves do not differ from those commonly employed in inorganic chemistry, except that metallurgical chemists have developed certain rapid methods of determination not always familiar to the general chemist.

The ordinary chemical specification covers only the solid elements contained in steel. There is, however, increasing evidence that the presence of gaseous elements, such as nitrogen and hydrogen, materially affects the properties of metals, thus lending support to the contention of some British crucible-steel melters of the early part of the 19th century that they could judge of the character of a steel by the smell of a fresh fracture (the smell possibly resulting from a very faint evolution of hydrogen sulphide). There are (still somewhat uncertain) methods for determining the nitrogen and hydrogen entrapped or dissolved in steel, but none applicable in shop practice, and hence no insertion of any specification in the chemical analysis as to occluded or dissolved gases in steel would be acceptable to a steel mill. Furthermore, what is known in regard to the influence of gases in steel is as yet too fragmentary to be of real practical value.

Determination of the Structure of Steel and Iron by Microscopy and Reflection Photography

As stated in many instances in the preceding chapters, the two main constituents of steel, carbon and iron, and some of the alloying elements combine with each other in many ways within the same quantitative relation. Thus, it may happen that two materials showing the same chemical analysis will prove to be widely different from each other. As an instance of this may be cited white iron and malleable iron, pearlitic and martensitic or pearlitic and sorbitic steels, etc. In fact, the structure of ferrous materials has far more influence on their industrial properties than their analysis, as it is the structure of these materials which primarily defines their ability to resist the various chemical, physical, and thermal stresses to which they are subjected in the course of the performance of their various tasks. It becomes of very great importance, therefore, to find a method that will permit of an insight into their structure, which in this case means the size of the grains and their location with respect to each other, the compounds in which the iron, carbon, and other elements occur in the metal, and the uniformity or lack of uniformity of the structure throughout the various sections of a given body of metal. It is also important to discover whether or not there are planes of weakness in the metal or minute inclosures of foreign substances that might become starting points of possible future cracks. None of these factors can be discovered as far as we know by means of either physical tests or chemical analysis, but the microscope offers a powerful tool for the investigation of these phenomena, especially when combined with various photographic methods. Of these latter there are two classes, one using visible light as an illuminant, and the other using X-rays. In order to avoid confusion between the two, the former will be called here "reflection" photography, as it operates by rays reflected from the object to be photographed on the sensitive plate or film, and the other "X-ray" photography, as it is effected by rays penetrating *through* the object photographed to a sensitive plate or film on the side of the object opposite to that where the source of the rays is located.

As regards the microscope, which includes the common magnifying glass, there are two ways of applying it: one to a fracture, especially a fresh one, of a metal, and the other to a specially prepared surface. The former, except in some unusual cases, gives only a rough idea as to the structure of a metal, but may be of considerable use in helping to discover local flaws which led to fracture, such as slag inclusions, blowholes, cavities, previously unknown surface defects, etc. The great importance of microscopic, photomicroscopic, and direct photographic examination is due, however, to the information obtained by the investigation of specially prepared surfaces.

In order to obtain a view of the structure of a metal under the microscope, it is necessary to prepare what is known as a "microsection," which means that the surface of the metal should be polished free from scratches and chemically treated (etched in a certain manner so as to bring out the various constituents of the metal).

The first operation is usually that of sawing off a piece of suitable size, which may be done with a hacksaw or thin grinding wheel. Either method will give a surface of irregular texture and more or less deeply scratched. The next operation is therefore to remove the deep scratches, which can be done on an ordinary bench grinder with emery or carborundum wheels. It is often necessary to perform this operation with a stream of water playing on the piece to prevent it from heating. The coarse grinding is followed by fine grinding, an operation which requires a good deal of skill to be performed properly. The operation known as burnishing cannot be used in the preparation of microsections, because although it does produce a very smooth-looking surface, this surface is obtained by a sort of smearing over of metal in a surface layer which disappears on etching and leaves below an irregular surface. After the specimen has been ground on the finest emery paper (No. 000 or 0000 as the case may be), it is polished, which is done by means of a piece of broadcloth to which polishing powder and water are applied. When all the fine scratches have been removed the section is washed in water and placed in a small dish of absolute alcohol or ether to remove the water and grease from the surface. The specimen is then dried in a blast of air and when possible placed in a desiccator to preserve the polished surface. The section thus obtained may be directly examined under the microscope when the constituents of the metal are of sufficiently different color to be distinguishable without further treatment. Direct examination will, for example, show graphite in cast iron or slag and manganese sulphide in steel. Once on a while it may lead to erroneous conclusions, as, for example, it was probably as a result of direct examination that the belief in the fibrous structure of wrought iron arose. Under a low magnification wrought iron with its strings of slag does give an impression of being fibrous, even though the metal itself, as we now know, is crystalline. In the majority of cases, however, it becomes necessary to develop the surface in order to gain a more complete insight into the structure of the metal. This development is done usually by chemical means, although other means are available. One of the most interesting of these is the so-called "heat tinting," based on the fact that steel heated in the air forms oxides, the colors of which depend on the thickness of the film formed and its character, both of which in their turn depend on the composition of the material. The result is that a series of interference or temper colors is produced. This method was used for the determination of phosphorus enrichment in steel, also to distinguish phosphide of iron from the carbide of iron in white cast iron, etc. However, the application of this process thus far has been only a limited one. The practice of chemical development or etching is based on the idea that the reagents used do not attack all the constituents of metals in the same manner. It is like making a mosaic out of bits of tile and bits of sugar and then applying a stream of water which will wash out the sugar and reveal the distribution of the pieces of tile. In order to obtain a clear picture of the etched surface a considerable amount of knowledge is required in the selection of the reagents, and it is usual to specify what reagents have been used in etching a specimen inspected or photographed. Etching reagents may be applied either at room temperatures or slightly above them, or at quite elevated temperatures of the order of molten calcium chloride. This latter is used for the purpose of developing the structure stable at certain high temperatures.

Ordinary etching reveals the structure of a material but fails as a rule to give information as to strain lines, i.e., alterations in the body of steel caused by stresses. A process has been lately developed employing as an etching medium a strong acid solution of copper chloride over a properly prepared steel, and it is claimed that this brings out a set of lines which from all information available appear to be strain lines.

Deep etching develops differences in color between different grains, some appearing dark and others light. It may be stated in this connection that notwithstanding the very great progress

already made and the results achieved, microscopy as applied to the investigation of metals is still more or less in its infancy and, for example, is far behind in its technique as compared with the art as developed by the biologist. Thus, next to nothing has been done to obtain reagents that will produce distinctive colors in the various constituents of steel beyond what may be called degrees of grayness.

Still deeper etching produces within certain grains geometrical figures which are called "etching pits." These pits approximate a definite geometrical form, such as a triangle or rectangle, and within any particular grain have the same form and orientation. They furnish additional evidence of the crystallinity of metals.

The surface prepared in any of the manners described may be investigated by the naked eye or under the microscope. It is comparatively rare that the former can be used—only in such cases as zinc or iron galvanized by the hot-dip process, where the crystals show quite prominently. Usually magnification is necessary in order to obtain useful results. Essentially the metallurgical microscope works in the same manner as all other apparatus of the same kind, but the details of construction make it different from the microscope used in biological work.

In ordinary work such as routine investigations of metals, magnifications of 50 or 100 diameters are sufficient as they bring out the general distribution of such constituents as pearlite, cementite, and martensite, and show the mode of distribution and appearance of graphite particles. They also reveal sufficiently for ordinary purposes the presence or absence of impurities and the degree of uniformity of the metal over a given cross-section. Where more exact metallurgical knowledge is required, magnifications of 500, 1000 and even more diameters are resorted to. Figs. 2 (No. 7) and 3 on pages 343 and 344 of the May issue show similar structures, in one case under a magnification of 100 diameters, and in the other, of 1840 diameters. The appearance of the metal in these two views is strikingly different, and it may be suggested that for those who are not expert metallurgists accustomed to work with structures under high magnifications, lower magnifications may prove to be a safer guide, simply because one is naturally more familiar with the way a sound metal looks under the common magnifications of, say, 100 diameters, and the structure under that magnification offers a better ground for comparison. On the other hand, for research purposes the higher magnifications are of unquestionable value. In fact, an editorial in *The Iron Age* of September 11, 1924, discussed the possibilities of magnifications of 5000 diameters, and expressed the belief that they would tell us, for example, of the real atomic spacing and the nature of martensite. Here again metallurgical microscopy, being only a fairly young science and for a long time having been hampered by lack of proper recognition, has not yet reached the same stage of development as, for example, microscopy as used in physical chemistry and biology. In these sciences magnifications far in excess of 5000 have been successfully employed, and the ultramicroscope even permits one to see particles of matter much smaller than the shortest wave of visible light. The ultramicroscope and the use of the highest possible magnifications have been the means of revealing such mysteries of nature as the structure and behavior of colloidal solutions of metals, and the life and mode of propagation of some of the minute micro-organisms. There is every reason to believe that higher microscopy together with X-ray analysis will contribute powerfully to our knowledge of the structure of metals.

There is another field where microscopy might afford some useful knowledge, but the difficulties in its application, particularly to metals like steel, are so enormous that at least for the present but little hope can be entertained that it can be done. This is the field of investigation of metals in their molten state and during the critical period of solidification.[1]

Illumination

In general, illuminants used in microscopic examination of metals can be divided for convenience into two groups: those which are used to produce the so-called "critical" illumination—in which the source of illumination is reproduced by the objective on the surface of the microsection—and those used in a projection system. Critical examination is intended principally for visual observation, while the other systems are designed to give a stronger illumination, such as is needed for photomicrography. The illuminant may be a gas light or an incandescent bulb such as the concentrated-filament Mazda lamp, and for photomicrography the calcium light and arc light. It has been suggested[2] that polarized light be used for the examination of objects. The attempt has not been quite successful but the idea is interesting. In a polarizer, such as a crystal of iceland spar or tourmaline, a beam of light breaks up into two rays of equal intensity; one known as the ordinary ray is reflected through the sides of the crystal and absorbed, while the other, the extraordinary ray, passes on through and is said to be a ray of plain polarized light.

The next thing with which one has to deal in metallurgical microscopy is the manner of illuminating the metal surfaces which have been polished and etched. Obviously only reflected light can be used, which is the reason why this class of examination has been referred to above as reflection microscopy or photography; but the incident light may be made to fall upon the surface in several ways, and respective methods of illumination are known as oblique, vertical or normal, and conical. Oblique illumination is produced when a suitably arranged beam of light falls upon the metal surface from some direction outside the lenses of the microscope. It is very simple and valuable, especially where it is desired to take account of the differences of level and surface configuration. On the other hand, the optical effects produced may be exaggerated or distorted. Minute surface defects are apt to be emphasized and slight differences of surface texture appear as vivid contrasts of brightness. For certain practical reasons oblique illumination can be conveniently used only with lower powers of magnification, and is employed but little in photomicrography.

In vertical or normal illumination the light is caused to fall upon the surface of the specimen in a direction at right angles to the surface; i.e., if the microscope is used in the vertical position, the light falls upon the specimen vertically from above. Only a small part of the light used is actually employed to form the image, but this amount is sufficient for practical purposes, and with certain appliances very clear views can be obtained. One of the disadvantages of normal examination is that steel constituents are seen only in outline, no shadows being cast, while it would be obviously desirable to view microscopic objects in a more natural way, i.e., to see them in relief. This may become important at higher magnifications. To meet this situation a new method known as "conical illumination" was developed (by Harry S. George). In this method an opaque disk is placed in the optical system of the microscope in such a manner that an image of the disk is formed near the back lens of the objective, producing a hollow cone of light in the objective with the apex of the cone on the object. Because of the fact that the rays of light in this case are more nearly parallel to the optic axis and therefore are reflected back through the objective from plain surfaces, they make them appear bright and impart a natural relief effect to the appearance. Moreover, this method is adaptable to high-power work.[3]

Photomacrographs and Photomicrographs

It is but a natural step from the investigation of surfaces of metals by the microscope to the recording of their appearance by photography. The production and preparation of photomicrographs in metallurgy does not differ from the process used in other arts and therefore need not be especially described here. Mention may be made, however, of the fact that two main kinds of photographs may be taken: the "photomacrograph," where the picture is of the same size as the original, and the "photomicrograph," which is taken through a microscope and gives a magnified view of the original. The purposes of the two are entirely different. In photomicrography the surface of the metal is etched in such a manner as to produce irregularities on the surface which will be shown by the reflection of the light. In this way the grain structure and the distribution of the various constituents of the metal are brought out. In photomacrography only the general structural distribution is brought out, the purpose of photomacrographs (which includes sulphur prints) being not to ascertain the grain structure as such, but to determine whether the article or ingot is of uniform chemical composition and to estimate its general structural distribution. Photomacrographs are produced by polishing the sample, etching it, and then photographing the surface. There are two ways of doing the latter, one by means of ordinary photo-

graphic apparatus, and the other—known as the contact process—by using specially sensitized paper which is laid directly on the etched surface. In this latter the etching materials and the material with which the photographic film (which may be of silk) is impregnated are of such a character that sulphide and phosphide inclusions are affected in such a manner that the parts of the film in contact with them change color and become lemon-yellow for phosphorus and black for sulphide spots. (Such photographs are also known as "sulphur prints.")

X-Ray Photography

X-ray photography has two entirely independent purposes: one to investigate metal articles with the aim of discovering possible defects, such as blowholes, contraction cavities, slag inclusions, etc.; the other, to investigate the crystalline structure of metals. The former has been applied successfully, for example, at the Watertown Arsenal, Watertown, Mass.,[4] where about 200,000 volts are impressed on the Coolidge tube, with an exposure of about one minute for 1 in. thickness of steel, about five minutes for 2 in. thickness, and about thirty minutes for 3 in. It requires a certain amount of practice to read X-ray films correctly, but once this is attained these films show the location, the approximate size and shape, and, with considerable certainty, the cause of defects in steel castings. Occluded sand, cavities resulting from incomplete deoxidation of the metal in the furnace, cavities formed by gases entering the metal during solidification from the core and mold, piping or shrinkage cavities resulting from inadequate feeding from risers during solidification, cracks caused by unyielding cores or failure to promptly relieve the mold, imperfections in welding and burnt-in metal, can all be individually detected.

Among other things, it has been found that where a number of castings have to be made from a given pattern, X-ray analysis can be employed to a certain extent as a means of improving the design of the pattern, thus insuring better castings. The principle on which X-ray photographs are used to discover a defect is that the rays which pass through a defect such as a blowhole, and therefore through a smaller thickness of metal than the sound parts, reach the film with greater intensity and form a much darker spot on the film, the outlines and size of the spot corresponding closely to those of the defect.

X-ray analysis has also been employed with great success as a means of determining the crystal structure of metals.[12] The principle used is similar to that of the ordinary diffraction grating, which consists of a piece of glass or metal on which are ruled a large number of parallel and equidistant lines. A beam of monochromatic light falling upon such a grating is diffracted through an angle depending on the wave length of the light and the spacing of the lines on the grating. Because of this the grating can be used for the analysis of light and for the exact measurement of the wave length of any particular portion of the spectrum. If desired, monochromatic light of known wave length may be used to determine the spacing of the lines on a grating. As the wave lengths of X-rays are very short, about $^1/_{10000}$ as long as those of visible light, it is impossible to construct a grating of the necessary close spacing by the usual method of ruling lines, but a successful attempt has been made to use the ordered arrangements of the atoms or molecules and crystals for the investigation of X-rays. After it had been found that the spacings of the planes of atoms or molecules were of the right order of magnitude and after it had been determined that X-rays were of the same nature as those of ordinary light, their wave lengths were measured. The process was then reversed and monochromatic X-rays of known wave length used to measure the spacing of the planes of atoms in a crystal.

Examination of the inner structure of metals by X-rays has not only a great scientific interest in that it reveals the structure of the metals, but a practical value as well. It has been applied, for example, to the examination of the inner structure of strained metals such as drawn copper wire. Experiments show that a copper rod composed of an irregular mass of small crystals as a result of rolling or forging and being drawn into wire takes a fibrous structure, the arrangement of crystal lattices being transformed into a state of irregularity which may account for the changes in such properties as hardness and strength.[5]

Determination of Corrosion Resistance

There is really no such thing as a universal factor of corrosion resistance.[8] Materials which are highly resistant to one agent, such as sulphuric acid, may prove to be entirely incapable of resisting another one, such as nitric acid. Corrosion-resistance tests should always be made clearly with a view to the factors which may affect the material while it is in service; thus it would be entirely useless to test the iron members of an inland building for corrosion resistance to salt water. Because of the great diversity of corroding factors, numerous tests have been developed for corrosion resistance. The investigation made by the Bureau of Mines as to the corrosion resistance of various materials when exposed to mine waters[9] is a good example of the method used in carrying out such tests.

Quite often it is desired to know how a certain material will behave when exposed to corroding factors over a great length of time. Such is the case, for example, with soil pipe, which, under certain conditions, may not start corroding until it has been in the ground for a period of, say, 10 to 20 years. In such cases it is desired to have some quick test that will within a reasonable period, of, say, a couple of months, give a more or less reliable indication as to what behavior may be expected from the material over a long time. Such tests are called "accelerated corrosion" tests, and it should be clearly understood that by no means all of them are fully reliable. Whenever such a test is used it is well to accept its conclusions with a certain amount of circumspection and to investigate whether it has been used on a similar material long enough to afford a basis of comparison between laboratory results and the behavior of the material tested under actual service conditions.

The subject of corrosion resistance is frequently rendered more complicated by the application of protective media to the metal parts.[10] The presumption in such cases is that the protective medium, such as paint, tar, etc. will help delay or prevent corrosion. Whether it does so or not is a matter that it is well to determine and not take for granted, because in matters dealing with corrosion things do not always work out quite as simply as one would offhand expect them to. For example, one might suppose that two layers of paint would protect metal from corrosion better than one layer, and yet cases have been found where two layers reduced the amount of corrosion protection to less than that afforded by one layer.

Another element in connection with corrosion tests which has to be borne in mind carefully is that of seeing that the tests involve all the factors present in actual service. For example, if there is a possibility that stray currents from electric traction lines may be flowing where the pipe or other part under consideration is to be laid, tests of corrosion by electrolysis should be carried out. In districts like Pittsburgh, sulphurous, hydrofluoric, and silico-hydrofluoric acids may be present in soil waters though being introduced therein by rain and condensation from the air into which they are projected by the numerous steel mills, glass works, and chemical plants. Therefore tests for the corrosion of parts to be imbedded in Pittsburgh soil which were carried out with Croton water in New York City might not give valuable results. It should be also clearly understood that in a complete machine a member may corrode with great rapidity because of contact with, or even nearness to, other metal parts made of materials having a different electric potential. Hence, in testing for corrosion attention should be paid to the influence of other parts of the structure. One famous case is that of a yacht having a steel hull and monel-metal sheathing where violent corrosion of the steel parts took place, obviously due to high electric potentials set up by the contact between steel and monel metal in sea water. Here corrosion tests of either steel or monel metal alone would not have given any information that would have been useful to the designer of the yacht.

In many cases only the surface of a metal is protected against corrosion, and in these it is important to consider whether in the use of the article this surface is likely to wear off, and in that event what happens to the metal. It is also important to note whether parts of the surface may be cut away, as, for example, in cutting threads on a pipe, and what will happen then as a result of the interaction of the protected top layer and unprotected lower layers. Galvan-

izing, sherardizing, and galvannealing (zinc coating) and nickel plating are the best-known methods of protecting the surface of the metal. Lead plating, cobalt plating, and chrome plating are receiving increasing attention. A different type of surface protection is presented by calorizing and chromizing, both of which consist in heating an iron or steel article in aluminum or chromium powder in an atmosphere of hydrogen under conditions which produce a sort of alloying action between the two metals, resulting in a heat-resisting, and to a certain extent corrosion-resisting, surface layer. It is important to remember also that the so-called "stainless steel" (steel containing a very low percentage of carbon and from 10 to 14 per cent chromium) is stainless only if the surface is polished.

Often a photomicrograph of a material may give an idea, very approximate only of course, as to the behavior of a material when exposed to corroding agencies. In general, the more uniform the structure of a material is, the less it is likely to be subject to corrosion.

Determination of Electrical Properties

This is a subject with which mechanical engineers have seldom to deal, electrical properties of metals such as electric conductivity, magnetic properties, electrolytic potential, permeability, etc. being of greater interest to electrical engineers, who have developed very precise methods of testing for their determination.

Determination of Physical Constants

There are quite a number of such constants, some of which are of interest to mechanical engineers while others are not. The melting point has been fairly closely determined for the great majority of metals and their alloys, and the values can be found in handbooks. The latent heat of fusion has been determined for a number of metals and this information is scattered through a number of publications. It is not usually of interest to mechanical engineers. The coefficient of thermal expansion has been determined for a number of metals and alloys and varies from zero at ordinary temperatures for invar (an alloy of iron and nickel) to very appreciable values for such alloys as nichrome and metals like zinc. This is obtained directly by raising the temperature of a bar of a given length through a desired range and measuring it before and after heating, and is quite well known for the great majority of metals and alloys. It is important in this connection to remember that metals have two coefficients of expansion, i.e., the linear and the cubic, and in engineering work it is often well to distinguish between the two. There is a third factor belonging in a way to the same class, viz., contraction on freezing. The majority of metals (cast iron is one of the few exceptions of commercial importance) shrink on passing from the liquid to the solid state, a fact which has to be taken into consideration in the design of patterns for castings. In steel this shrinkage is assumed to be of the order of 2 per cent (say, $^1/_4$ in. to the foot).

Determination of Stability

This test is not necessary for all metals, but it so happens that certain metals change their structure with time and become brittle. This phenomenon is called "aging" and is said to affect duralumin, for example.

Because of this, when a new alloy is developed it is a wise plan to have samples retested at certain intervals to determine whether or not aging has to be considered. No reliable accelerated test for aging appears to have been developed as yet. There is another condition somewhat similar to aging which should not, however, be confused with it, namely, the deterioration of a material exposed to high mechanical or thermal stresses over a considerable period of time. Thus elevator cables lose their strength after a certain period of service; annealing containers become brittle, etc. Here we have to deal not with aging but with fatigue in one case and change of crystal structure in another. Because of this, where it is expected that a metal member will be in service under stresses, mechanical or thermal, approximating the danger line, it is well to institute tests for its structural stability under such conditions after various lengths of service. The somewhat indefinite expression "danger line" is used advisedly, because of the great variation in what it may imply.

A phenomenon somewhat similar to aging is likely to develop in metals subjected in service to high temperatures for great lengths of time. Such metals, unless of compositions specially adapted to this kind of service, will probably deteriorate and lose their strength. There is no standard quick test for this condition.

As to the methods of testing for stability, all that can be said is that they will vary with conditions of service; but in all cases it is advisable to have a microscopic examination of the metal carried out side by side with the physical tests, as in the vast majority of cases changes in physical strength are accompanied by recognizable changes in the structure of the metal.

Magnetic Analysis

The majority of tests to which metals are subjected, such as tensile tests, chemical analysis, etc., are of a destructive character, which means that the piece tested is destroyed during the test. Because of this the test can be carried out only on a sample, and the conclusion reached is limited strictly by the extent to which the sample tested represents the actual properties of the material. In certain branches of engineering where tests on models (and a test bar is after all nothing but a crude model of the actual article) are extensively used, an attempt has been made to develop what are known as "laws of similarity," or laws defining the relation between the properties of a small-scale model and a large-scale article. In aeronautics, in particular, where scale models are tested in wind tunnels, the law of dynamic similarity has been developed to a considerable extent.

Obviously, destructive testing can be used only on samples or on actual articles after they have outlived their usefulness, or finally in investigating causes of accidents which have already occurred. There would be but little profit in determining that an elevator cable is sound by tearing it in two, and it is desirable to have a method of non-destructive testing of materials even when their indications are only approximate. The magnetic testing of steel is such a method, as also is X-ray investigation.

Comparatively little has been published on the magnetic testing of steel. It is stated it was developed in a more or less accidental way. For some reason it was desired at the U. S. Bureau of Standards to make up several steel bars having the same magnetic permeability. This seemed to be a very simple matter, but when an endeavor was made to get such bars it was found that scarcely any two bars have the same permeability. A further investigation showed that the permeability of a piece of steel varies in a decided way with the slightest variations in its composition, and, for example, that the presence of pipe, slag inclusions, segregations or flaws causes a clearly noticeable change in the magnetic properties of the metal. This clearly indicated the possibility of using magnetic testing for the discovery of imperfections and variations in steel.

As an example of the actual method of testing may be cited the use of the "defectoscope," which is an apparatus invented by Dr. Charles W. Burrows and described in *The Iron Age* of October 28, 1920, pp. 1125–1128. This device comprises a magnetizing solenoid and a detector, the latter consisting of two test coils having the same number of turns and surrounding the specimen.

The magnetizing solenoid and the detector are rigidly connected together and are given a relative motion along the length of the specimen by means of a suitable motor which forms the third element of the system. As the detector occupies different positions along the length of the test material, it is threaded by an induction which depends upon the nature of the specimen. If the specimen is not quite uniform the magnetic induction threading one of the coils of the detector is different from the magnetic induction threading the other coil. The result is the electromotive force generated in one of the test coils is different from that generated in the second test coil. Consequently a small differential electromotive force is impressed upon the detector system every time it passes over the magnetic inhomogeneity.

Determination of Machinability

There are no standard tests for machinability, cold and hot working, and forging. In ordinary steels the behavior in respect to these factors can be predicted roughly from the composition of the steel and its heat treatment, and often depends far more on

the latter than on the former. In new alloys it has to be determined by test.

As regards machinability, however, it should be noted that in a large number of cases this depends also on the uniformity of the structure of the steel. In a soft steel hard spots may be encountered which make the machining very difficult. Chromium steels are particularly subject to this condition and so are certain kinds of cast iron. This condition may be determined at times by taking photomicrographs at various spots, but sometimes only by actual tests. Attempts have been made to determine the machinability of a material by measuring its surface hardness. Such a test may give valuable results provided that a sufficient number of spots on the surface of a metal are tested, and provided further that the test is sufficiently delicate to determine not only the average hardness but also the actual hardness of the entire surface. Where none of the short-cut methods are applicable, only an actual trial can be used. Where a test for machinability is made the following information should be available as supplementary to the actual cutting results: Method of casting, forging, or rolling the samples; whether or not the casting skin has been removed, as by grinding or pickling; what heat treatment, if any, the test piece has been subjected to (this information is not necessary when dealing with a rolled product, but may be of value in dealing with forged products); what cooling liquids, if any, were used in the cutting test; cutting-tool material. If cutting tests indicate the presence of hard spots an investigation should be made to determine their nature and origin as well as the possibility of removing them by proper heat treatment.

Tests for cold and hot working are usually made only when dealing with new alloys as the behavior of the standard steels under these conditions is well known.

Determination of Erosion Resistance

Erosion is a form of wearing away encountered in guns and the blades of steam and gas turbines. While there is no standard test for its determination, an article in the *Brown-Boveri Review* for December, 1924, describes a test by which erosion resistance may be determined in something like 70 hours. The method consists in placing a carefully weighed specimen in such a way that dry saturated steam impinges on it at a certain angle. After the test the specimen is carefully dried and reweighed, the decrease in weight serving as a measure of the liability to erosion of the material concerned. The appearance of the specimen also indicates—often very clearly—the erosion strength of a material.

From this test it has been found that increase in hardness due to proper heat treatment produces a notable decrease in the loss due to erosion.

Spectroscopic Analysis

Spectroscopic analysis has been primarily used principally for the determination of constituents of materials occurring in such minute quantities that it is difficult to identify them by ordinary chemical analysis. The equipment used in scientific laboratories is entirely unsuitable for ordinary metallurgical work, and it is extremely seldom that elements occurring in such minute quantities as to warrant the application of spectroscopy affect the structure of metals or their properties to an extent that would interest an engineer. Lately, however, apparatus has been placed on the market in England that enables the presence of nickel and chromium in steel to be detected immediately, even by an unskilled observer. It is stated that with a few days' experience with bars of known nickel and chromium content, the observer learns to judge the approximate percentage present.

The spectroscope employed consists of a substantial casting with two screw-focusing eyepieces at one end and a stout protective glass plate at the other. The method of use is extremely simple. In the case of the instrument designed for testing bars in the rolling mill or warehouse, one bar of carbon steel is held in a suitable wooden frame, and the bars to be tested are then placed in position on V-supports one by one as rapidly as possible, connection with the electric mains being provided through a suitable resistance giving about 5 amperes. Direct current of from 150 to 250 volts is necessary. The arc is struck by touching both rods simultaneously with a third rod of iron or carbon steel (insulated by pushing over one end of it a piece of ordinary rubber tube). Removal of this rod strikes the arc, and the observer at the spectroscope is able to state immediately whether or not the sample contains an important quantity of nickel or chromium. With the aid of three or four standard samples containing various percentages of nickel and chromium he can soon accustom himself to state also the range of percentage within which the nickel or chromium content lies.[6]

Testing by Sound

This is one of the oldest tests, the expression "steel that rings true" having been used from the oldest days by blacksmiths and swordmakers. For various reasons it has not yet developed into a practical method of testing, but its possibilities were indicated by Prof. Henry M. Howe in his presidential address before the International Association for Testing Materials at the meeting in New York in 1912, when he stated: "Who shall say that the pitch or volume or timbre of sound emitted by a rail as a result of a given excitement may not be made to disclose pitilessly its hidden defects and to measure the fitness not alone of the material of which it is composed but of the rail as a whole structure? Or, giving rein to our fancy, we hear the inspector report, 'This 100-story building indeed responds to G sharp, but its timbre has this abnormality and these harmonics are exaggerated.' "

Sound testing in a somewhat modified form has recently been employed to detect flaws developing during the process of forging as a result of stresses set up during the heating and the cooling processes through which the forging passes in the course of its manufacture. The instrument used does not detect flaws in a cold forging. Its operation is based on the fact that flaws of this character, which are also called "clinks," are accompanied by a ringing noise at the time of their formation, and detection of this sound by a continually operating recording apparatus forms the basis of the "Clink Detector," as the instrument has been called by the makers. The detector is attached to the forging under observation during the heating and cooling process, and on a clock-driven recorder which is electrically connected to the detector a record is obtained of any shock or disturbance occurring in the body of the forging. The instrument can also be adapted for recording the temperature of the forging during the various processes of manufacture.[7]

References

[1] Francis F. Lucas, High-Power Photomicrography of Metallurgical Specimens. Transactions of the American Society for Steel Treating, November, 1923, pp. 607–634.

[2] Robt. G. Guthrie, Use of Various Kinds of Light in Metallography. Transactions of the American Society for Steel Treating, April, 1923, pp. 710 to 719 and 757.

[3] Harry S. George, Conical Illumination of Metallography. Transactions of the American Society for Steel Treating, August, 1923, pp. 140–161.

[4] T. C. Dickson, X-Ray Examination of Metals at the Watertown Arsenal, Watertown, Mass. Presented at the Annual Meeting of The American Society of Mechanical Engineers, December, 1924; abstracted in the Mid-November issue of Mechanical Engineering, p. 773.

I. E. Moultrop and E. W. Norris, X-Ray Examination of Steel Castings. Mechanical Engineering, vol. 47, May, 1925 (Sec. 2), pp. 392–399.

[5] Zay Jeffries and Robt. S. Archer, The Science of Metals, 1924, pp. 51–55; and paper by Prof. W. H. Bragg before the Faraday Society, April 29, 1919, reprinted in *Engineering*, May 2, 1919, pp. 576–578.

[6] Spectrometers for Detecting Nickel and Chromium in Steel. *Iron and Coal Trades Review*, vol. 109, no. 2961, Nov. 28, 1924, p. 870.

[7] *Engineering*, November 7, 1924, p. 658.

[8] J. A. N. Friend, Corrosion of Iron. Iron and Steel Institute, Carnegie Scholarship Memoirs, v. 11, 1922.

Ulick R. Evans, Corrosion of Metals. Longmans, Green Co., N. Y., 1924.

[9] Robert J. Anderson and George M. Enos, Corrosion in Mine Waters and Recent Investigations of It by the U. S. Bureau of Mines. Trans. American Society for Steel Treating, vol. 6, no. 5, Nov., 1923, pp. 587–610 and 647.

[10] John S. Coye, An Investigation of the Protective Value of Structural Steel Paints. Iowa State College of Agriculture and Mechanical Arts, vol. xvii, no. 49, Bull. 54, 1919.

[11] The Hardness of Metals and Hardness Testing, Mechanical Engineering, vol. 46, June, 1924, pp. 360–362; cp. also Symposium on Hardness, Mechanical Engineering, vol. 46, Nov., 1924, pp. 701–702, being abstracts of papers on hardness presented before the annual meeting of the American Society for Steel Treating, Boston, 1924.

[12] Cp. Chapter II—The Crystalline Structure of Ferrous Metals, in the June, 1925, issue of Mechanical Engineering, pp. 479–484, and references on p. 484.

Endurance Properties of Metals[1]

Recent Investigations—Endurance Range of Steel—Endurance Properties Non-Ferrous Metals—Effect of Cold-Working and Annealing on Endurance and Other Properties—Influence of Chemical Composition

By D. J. McAdam, Jr.,[2] Annapolis, Md.

Failures of metal machinery parts after subjection to many cycles of a range of stress are known as "fatigue" failures. Such fatigue failures exhibit a characteristic type of fracture: the fracture is highly localized, the adjacent regions show little if any evidence of deformation, and part, at least, of the surface of fracture often appears crystalline.

Fatigue failures never occur unless the metal has been subjected to a range of stress. The range may be between a tensile and compressive stress, as in a piston rod or rotating axle; or it may be between zero and a tensile stress, or between a maximum and minimum tensile stress. Or the range of stress may be torsional, between a positive and negative limit, between zero and an upper limit, or between a maximum and minimum stress in the same direction. "Fatigue" of metals is more dependent on the extent of the stress range than on the values of the stress limits.

The highly localized, often crystalline, fractures observed after fatigue failure led to the theory that such failures are due to "crystallization" of the metal. By means of the microscope this theory was long ago disproved. We know that all metals are crystalline and we know that subjection to a range of stress does not cause recrystallization of the metal or growth of the crystals. Nevertheless it is surprising how the erroneous idea of failure by "crystallization" still persists, even among technical men. Within the past few months the Naval Experiment Station has received an inquiry from a metallographist in regard to "crystallization" by fatigue. An inquiry has also been received from the superintendent of motive power of a large railroad for information about the life of axles. He contemplated placing a definite time limit on axles in service and removing them before they crystallized and failed.

The microscope reveals the real mechanism of fatigue failure. To understand this mechanism it is necessary to understand the mechanism of the plastic deformation of metals. The microscope shows that all metals are made up of irregularly shaped grains, each of which is a crystal. Fig. 1 shows such irregularly shaped grains in fully annealed nickel. When a metal is plastically deformed each of the crystals is deformed. Cold-rolling, for example, elongates the crystals in the direction of rolling. This is illustrated by Fig. 2, which shows the microstructure of cold-rolled nickel.

The specimen shown in Fig. 2 was polished and etched after the cold work had been done. If, however, a specimen be polished and etched and then slightly deformed, the mechanism of the crystal deformation is made apparent. The same specimen of annealed nickel that is shown in Fig. 1 was again plastically deformed by squeezing it in a vise. The effect of the deformation on the microstructure is shown in Fig. 3. In each grain are "slip lines" due to gliding of the metal along planes of crystal symmetry, such as planes parallel to a face of an octahedron or cube. The "slip" of a crystal along a series of parallel planes of symmetry is similar to the interfacial sliding of cards in a pack. It will be noticed in Fig. 3 that throughout each grain the slip lines form one or more series of parallel lines, but that the direction of the slip lines varies from grain to grain. The grains, therefore, are crystals arranged with random orientation.

Slipping of a crystal along planes of symmetry strengthens these planes and hardens the metal. The hardening of a metal by cold-working has been explained on the assumption that relatively strong amorphous metal is formed along the gliding planes, and that this strong interfacial cement offers increased resistance to further gliding.

When cold-worked metal is heated to a temperature that depends on the material and on the degree of cold-working, recrystallization begins. New grains appear at the boundaries and on the slip planes of the original grains that have been distorted by cold-working. With increase in the temperature or time of anneal, the new grains increase in number and size at the expense of the old distorted grains, until finally the material is entirely recrystallized. With further increase in temperature or time of anneal the recrystallized grains increase in size.

The effect of temperature of anneal on cold-worked nickel is illustrated by Figs. 1, 2, 4, 5, 6 and 7. When the material shown in Fig. 2 is annealed for 30 min. at 1100 deg. fahr., the first evidences of recrystallization are visible. As shown in Fig. 4, a few dark streaks and patches appear; these consist of many small new grains. After annealing at 1175 deg. fahr. the new grains have increased in size and number as shown in Fig. 5. After further increase in temperature of anneal to 1200 deg. fahr., the proportion of recrystallized grains has increased at the expense of the original distorted grains as shown in Fig. 6. After annealing at 1225 deg. fahr., most of the material has recrystallized as shown in Fig. 7; a few large, distorted grains, however, are still visible. After further increase in the temperature of anneal to 1550 deg. fahr. the material as shown in Fig. 1 has entirely recrystallized and there has been considerable growth of the recrystallized grains.

When a crystal is subjected to a cyclic range of stress of sufficient magnitude, microscopic cracks start, probably at regions where slip has occurred. These microscopic cracks spread and combine until the section is so weakened that it fails.

It is important to know something about the various factors that cause fatigue of metals. By knowledge of these factors it is possible to determine what qualities a metal should have to withstand fatigue under various conditions of service. These qualities have been designated "endurance properties of metals."

Recent Investigations of Endurance Properties of Metals

An investigation of fatigue of metals was made by Wöhler about 1871,[3] and scattered researches have been made at intervals since Wöhler's time. It is only within the past five years, however, that intensive investigation has been made of the endurance properties of metals in the light of the knowledge of heat-treatment based on metallography. For the past five years this subject has been investigated at the University of Illinois,[4,5,6,7] at the Naval Experiment Station,[8,9,10,11 12,13,14,15,16,17] and at other laboratories. Until

[1] Presented by permission of the Secretary of the Navy before the Baltimore Local Section of The American Society of Mechanical Engineers, Baltimore, Md., November 1, 1924, and later revised.

[2] Metallurgist, U. S. Naval Engineering Experiment Station, Annapolis, Md.

[3] Investigations by Wöhler and others are discussed by W. C. Unwin in The Testing of Materials of Construction, chap. xvi, 1910.

[4] H. F. Moore and J. B. Kommers, An Investigation of the Fatigue of Metals. Bulletin 124, University of Illinois, vol. 19, no. 8, October 24, 1921.

[5] H. F. Moore, J. B. Kommers, and T. M. Jasper, Fatigue or Progressive Failure of Metals under Repeated Stress. Proc. A.S.T.M., vol. 22, part 2, 1922.

[6] H. F. Moore and T. M. Jasper, An Investigation of the Fatigue of Metals. Bulletin 136, University of Illinois, vol. 20, no. 37, May 14, 1923.

[7] H. F. Moore and T. M. Jasper, An Investigation of the Fatigue of Metals. Bulletin 142, University of Illinois, vol. 21, no. 39, May 26, 1924.

[8] D. J. McAdam, Jr., Endurance of Steel under Repeated Stresses. Chem. & Met. Eng., Dec. 14, 1921.

[9] Discussion by D. J. McAdam, Jr., of paper[5] by H. F. Moore, J. B. Kommers, and T. M. Jasper. Proc. A.S.T.M., vol. 22, part 2, 1922.

[10] D. J. McAdam, Jr., Endurance Properties of Steel: Their Relation to Other Physical Properties and to Chemical Composition. Proc. A.S.T.M., vol. 23, part 2, 1923.

[11] D. J. McAdam, Jr., Endurance Properties of Corrosion-Resistant Steels. Proc. A.S.T.M., vol. 24, part 2, 1924.

[12] Third Preliminary Report of the Joint Committee on Investigation of Phosphorus and Sulphur in Steel: Effect of Sulphur on Endurance Properties of Rivet Steel. Proc. A.S.T.M., vol. 24, part 1, 1924.

[13] D. J. McAdam, Jr., The Endurance Range of Steel. Proc. A.S.T.M., vol. 24, part 2, 1924.

[14] D. J. McAdam, Jr., Accelerated Fatigue Tests and Some Endurance Properties of Metals. Proc. A.S.T.M., vol. 24, part 2, 1924.

[15] D. J. McAdam, Jr., Endurance Properties of Alloys of Nickel and of Copper, Part 1. Trans. Am. Soc. for Steel Treating, Jan., 1925.

[16] Ibid., Part 2, Feb., 1925.

[17] Ibid., Part 3, May, 1925.

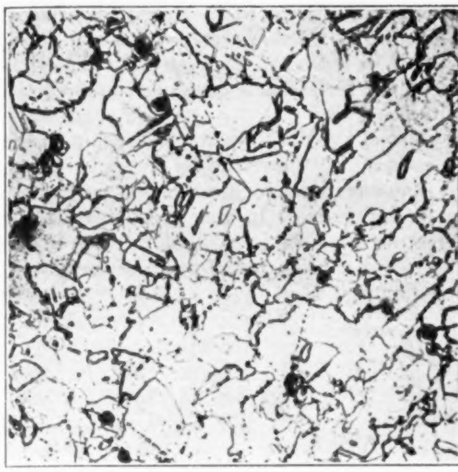

FIG. 1 NICKEL ANNEALED AT 1550 DEG. FAHR. × 200

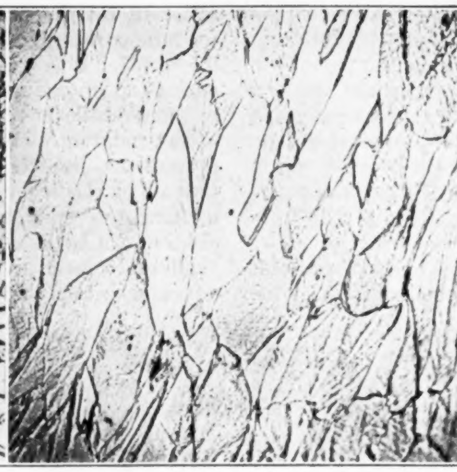

FIG. 2 NICKEL COLD-WORKED. × 100

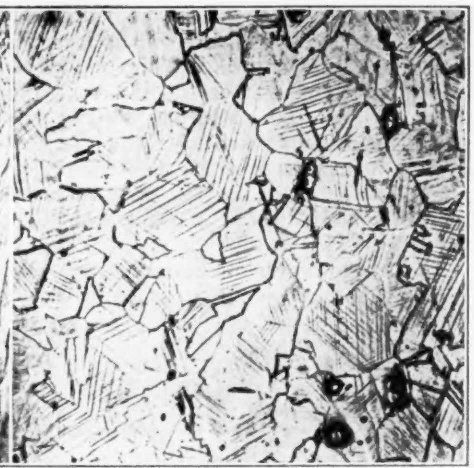

FIG. 3 NICKEL ANNEALED AND THEN DEFORMED IN A VISE. × 200

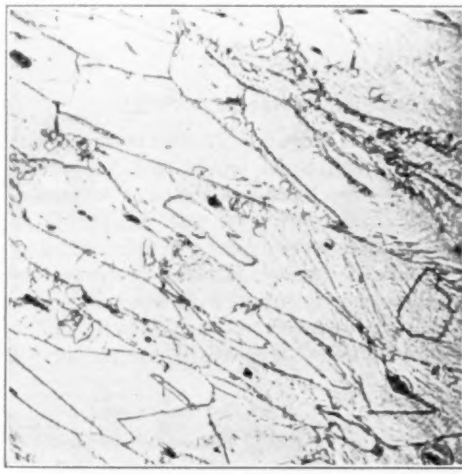

FIG. 4 NICKEL ANNEALED AT 1100 DEG. FAHR. × 100

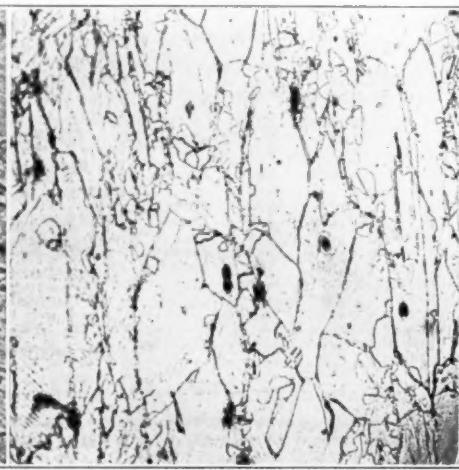

FIG. 5 NICKEL ANNEALED AT 1175 DEG. FAHR. × 100

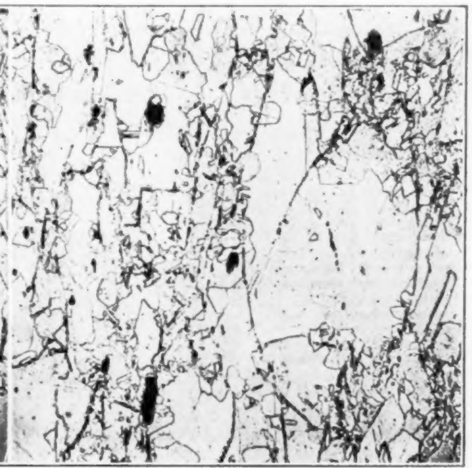

FIG. 6 NICKEL ANNEALED AT 1200 DEG. FAHR. × 100

very recently, chief attention has been given to investigation of the effects of a range of stress between equal positive and negative values. Moreover this investigation of the effects of alternating stresses has until within the last year been confined chiefly to steel, and only within that period has definite knowledge been obtained of the endurance properties of non-ferrous metals.[13,14,15,16,17]

INVESTIGATION OF ENDURANCE PROPERTIES OF METALS AT THE NAVAL EXPERIMENT STATION

Endurance properties of metals have been investigated at the Naval Experiment Station by means of a rotating-cantilever specimen. The specimen designed at the Naval Experiment Station[8,10,11] (Fig. 8) has a conical taper so that the stress is uniform within $1^1/_2$ per cent over a length of $1^1/_2$ in. In testing such a specimen the large end is held firmly in the axis of a rotating holder and bending stress is produced by a known weight supported from the other end by a bearing. Alternating torsion tests have also been made by means of a machine of the inertia type developed at the Naval Experiment Station.[18]

The results of each test are recorded on a stress-cycle graph. A semi-logarithmic scale is most convenient. With this scale the left-hand portion of each graph is definitely shown without making the entire graph excessively long. Moreover, on a semi-logarithmic scale it is possible to prolong a graph approximately by extrapolation to a position representing many times the experimentally determined cycles. This would not be possible with ordinary coordinates.

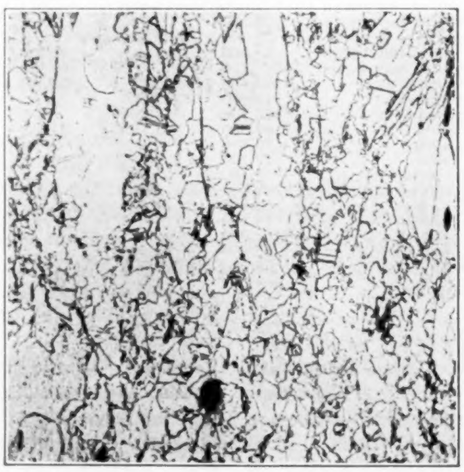

FIG. 7 NICKEL ANNEALED AT 1225 DEG. FAHR. × 100

THE ENDURANCE LIMIT OF STEEL

Typical graphs obtained with carbon and alloy steels heat-treated in various ways are illustrated by Figs. 9 to 12, inclusive. The chemical composition of these steels is given in Table 1, details of heat-treatment are given in Table 2, tensile properties in Table 3, and torsional properties in Table 4. Each small circle in these figures represents the stress and number of cycles endured by one specimen. A broken line is drawn through each series of small circles to represent average stress-cycle relationship. The steel represented by Fig. 9 was so uniform that the small circles are located on or adjacent to the broken-line curve. The steels represented by Figs. 10 to 12 also are of more than average uniformity. Such material was purposely selected so as to show clearly the form of the typical stress-cycle graph. The steels represented by Figs. 9 to 12 had been heated above the critical range and cooled as indicated in the figures.

Fig. 9 shows results obtained with steel having about 0.24 per

[18] D. J. McAdam, Jr., A High-Speed Alternating Tension Testing Machine. Proc. A.S.T.M., vol. 20, part 2, 1920.

cent carbon.[10] As shown in this figure, the slope of the stress-cycle graph decreases rapidly with decrease in stress until it becomes nearly horizontal between abscissas representing one and ten million cycles. The fact that beyond this point the curves are nearly if not quite horizontal is shown by the two specimens for each graph that remained unbroken after enduring several hundred million cycles. The stress at which the stress-cycle curve becomes nearly horizontal is known as the "endurance limit." The endurance limit of Material 0-3 is 26,000 and of Material 0-5 is 22,500 lb. per sq. in.

Fig. 10 shows results obtained with steel having 0.46 per cent carbon. The curves are arranged in order of decreasing tensile strength as listed in Table 3. It will be noticed that the "endurance limits" also decrease with decrease in tensile strength. The steepness of the left-hand side of each graph also decreases with decrease in tensile strength and proportional limit.

Fig. 11 shows results obtained with heat-treated nickel steel.[13] The stress-cycle graph consists of a curve with gradually decreasing slope ending in a nearly horizontal, practically straight line.

Fig. 12 shows results obtained with chrome-nickel steel. The endurance limit of the quenched and tempered material is about 67,000 lb. per sq. in. and of the annealed material, about 49,500.

The graphs shown in Figs. 9 to 12 are all of the same general form, although the curvature of the left-hand portion varies. All these graphs representing typical steels become practically horizontal at between one and ten million cycles.

Table 5 shows the relationship of the endurance limit to other physical properties. The endurance limits of the steels illustrated in Figs. 9 to 12 are given in column 8. In column 11 are listed the ratios of rotating-cantilever endurance limit to tensile strength (endurance ratios). This ratio for the steels listed varies from about 0.4 to 0.5. It is highest in heat-treated alloy steels. The alternating-torsion endurance limit for steels is usually about half the rotating-cantilever endurance limit.

The endurance limit of steel has little if any relationship to the proportional limit or elastic limit. Nevertheless it can be shown that a high elastic limit is an advantage for a machinery part whose usefulness depends on its endurance. In general, increasing the elastic ratio by heat-treatment results in a slight increase in the "endurance ratio." Moreover a high elastic ratio offers another advantage which will be discussed later.

TABLE 1 PERCENTAGE CHEMICAL COMPOSITION OF MATERIALS TESTED

Material	Material designation	C	Mn	P	S	Si	Ni	Cr	Cu	Sn	Zn	Fe	Pb
Carbon steel	O	0.24	0.45	0.009	0.007	..	...	..	...	..	...	..	...
Carbon steel	AD	0.46	0.68	0.015	0.021	0.11	0.13	..	...	..	...	..	...
Nickel steel	Q	0.31	0.64	0.026	0.028	0.13	3.35	..	...	..	...	..	...
Chrome-nickel steel	AK	0.41	0.44	0.010	0.022	0.27	1.89	1.05	...	..	...	..	...
Nickel, cold-rolled	CT	0.10	0.07	...	0.018	0.07	99.07	..	0.20	..	...	0.47	...
Nickel, cold-rolled	A	0.25	0.10	...	0.175	0.06	98.95	..	0.12	..	...	0.50	...
Monel metal, cold-rolled	BK	0.26	0.258	0.023	0.0063	0.065	76.66	..	21.28	..	...	1.40	...
Nickel-copper alloy	CU	0.016	0.36	0.006	0.009	0.002	55.23	..	44.18	..	...	0.44	...
Constantan, cold-rolled	CV	0.078	0.89	...	...	..	44.77	..	53.71	..	...	0.66	...
Copper, cold-drawn	CL	...	...	...	...	..	...	..	...	None	...	0.02	None detected
Alpha copper-tin alloy, cold-drawn	CK	...	...	0.026	...	..	...	..	95.0	5.06	...	0.03	0.01
Copper-nickel-zinc alloy, cold-drawn	CH	...	...	...	...	..	17.63	..	65.3	..	17.15	0.23	...
Copper-zinc-nickel alloy, cold-drawn	CG	...	...	...	...	..	10.89	..	60.08	..	29.05	0.20	...

TABLE 2 DETAILS OF HEAT TREATMENT OF MATERIALS TESTED

Material	Material designation	Heated to — deg. fahr.	Time held, min.	Cooled in	Reheated to — deg. fahr.	Time held, min.	Cooled in
Carbon steel	O-3	1600	30	Oil	1100	30	Furnace
Carbon steel	O-5	1600	30	Furnace	..	...	.....
Carbon steel	AD-6	1475	60	Oil	1100	120	Furnace
Carbon steel	AD-7	1475	60	Oil	1200	120	Furnace
Carbon steel	AD-1	1450	120	Furnace	..	...	.....
Nickel steel	Q-3	1475	30	Oil	1200	30	Furnace
Chrome-nickel steel	AK-4	1550	60	Water	1200	120	Furnace
Chrome-nickel steel	AK-1	1550	60	Furnace	..	...	.....
Nickel, cold-rolled	CT-5.5	550	60	Furnace	..	...	.....
Nickel, cold-rolled	CT-11	1100	60	Furnace	..	...	.....
Nickel, cold-rolled	A-16	1600	60	Furnace	..	...	.....
Monel metal, cold-rolled	BK-1	1600	60	Furnace	..	...	.....
Constantan, cold-rolled	CV-14.5	1450	60	Furnace	..	...	.....

TABLE 3 AVERAGE RESULTS OF STATIC TENSION TESTS

(Each value is average of two specimens except as indicated.)

Material	Material designation	Heat treatment	Tensile strength, lb. per sq. in.	Johnson's limit, lb. per sq. in.	Yield point, lb. per sq. in. (drop of beam)	Proof stress, lb. per sq. in.	Elastic limit, lb. per sq. in.	Proportional limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of area, per cent
Carbon steel	O-3	Quenched and drawn	66,000	....	42,250	....	....	39,250	38.5	69.2
Carbon steel	O-5	Annealed	55,120	....	33,600	....	....	31,250	38.7	60.6
Carbon steel	AD-6	Quenched and drawn	115,000	70,000	....	....	....	70,000	22.3	50.0
Carbon steel	AD-7	Quenched and drawn	105,080	65,350	....	....	....	65,350	26.3	55.0
Carbon steel	AD-1	Annealed	75,000	41,000	....	....	....	39,000	34.8	56.5
Nickel steel	Q-3	Quenched and drawn	97,500	....	80,000	....	....	79,000	26.0	67.5
Chrome-nickel steel	AK-4	Quenched and drawn	127,800	....	116,000	....	....	110,500	24.3	61.8
Chrome-nickel steel	AK-1	Annealed	102,400	....	61,500	....	....	56,000	26.8	56.3
Nickel, cold-rolled	CT	As received	†115,800	†78,300	....	†77,100	†67,900	†61,900	†16.3	†36.9
Nickel, cold-rolled	CT-5.5	Annealed	*113,900	*77,300	....	*75,000	*56,000	*53,300	*16.3	*37.5
Nickel, cold-rolled	CT-11	Annealed	*100,500	*61,700	....	*62,300	*50,000	*45,300	*22.5	*49.7
Nickel, cold-rolled	A-16	Annealed	70,400	**	....	14,300	6,000	**	47.8	54.8
Monel metal, cold-rolled	BK-1	Annealed	77,100	**	....	21,300	15,000	**	48.0	64.3
Nickel-copper alloy	CU	As received	65,400	22,800	....	23,300	19,600	17,300	47.0	77.5
Constantan, cold-rolled	CV	As received	103,300	**	....	54,700	32,400	**	14.8	70.1
Constantan, cold-rolled	CV-14.5	Annealed	69,400	24,500	....	25,400	23,800	21,000	48.3	79.0
Copper, cold-drawn	CL	As received	40,400	**	....	19,000	5,000	**	27.0	66.8
Alpha copper-tin alloy, cold-drawn	CK	As received	62,900	**	....	25,000	7,500	**	32.5	73.8
Copper-nickel-zinc alloy, cold-drawn	CH	As received	62,400	33,500	....	38,000	22,500	20,300	28.0	49.6
Copper-zinc-nickel alloy, cold-drawn	CG	As received	58,700	28,500	....	31,500	22,500	12,500	49.5	59.0

* Average of three determinations.
† Average of six determinations.
** Stress-strain graph curved from origin.

The Endurance Range of Steel

The results shown in Figs. 9 to 12 were obtained with a stress range between equal tensile and compressive stress; in other words, there was complete reversal of stress per cycle. Endurance tests with incomplete reversal of stress per cycle were made by Wöhler, and since then have been made by several other experimenters. As a result of these experiments varying conclusions have been drawn. In discussing these conclusions the following terms with definitions suggested by the author will be used.[10] By the "endurance range" is meant the algebraic difference between the maximum and minimum stress per cycle for a limiting range of stress within which the specimen will not fail by fatigue. For complete reversal of stress per cycle, for example, the endurance range is twice the endurance limit. The endurance range in this position will be called the "alternation endurance range."[13] The endurance range between zero and a maximum stress will be called the "repetition endurance range."

Moore and Jasper[6] investigated the endurance range of steel with widely varying ratios of maximum to minimum cyclic stress. They used a rotating specimen that could be loaded as a cantilever and subjected at the same time to uniform tensile stress by means of a spring. Their results as interpreted by them indicate that the repetition endurance range is only about three-fourths the alternation endurance range. About the same time that Moore and Jasper's results were published the author, as a result of some preliminary experiments to determine the "length of the endurance range in

various positions within and just beyond the edge of the elastic range," expressed the conclusion that the "variation of the endurance range within the elastic range is slight." The statement was also made that within the elastic range the repetition endurance range is apparently not more than about 10 per cent less than the alternation endurance range. A more complete investigation of the torsion endurance range,[13] including a number of carbon and alloy steels heat-treated to produce a high elastic ratio, led to the conclusion that for steel the variation of the torsion endurance range within the elastic range is not more than about 5 per cent. In this later paper the results of Moore and Jasper were discussed, with the conclusion that a right interpretation of their results might indicate that the variation of the bend endurance range is no greater than the variation of the torsion endurance range within the elastic range.

TABLE 4 RESULTS OF STATIC TORSION TESTS
(Individual results)

Material	Material designation	Heat treatment	Nominal torsional strength, lb. per sq. in.	Johnson's limit, lb. per sq. in.	Proportional limit, lb. per sq. in.	Angle of twist per linear in. at proportional limit, min.	Angle of twist per linear in. at break, deg.
Carbon steel	O-3	Quenched and drawn	53,440	....	22,940	20	327
Carbon steel	O-5	Annealed	46,640	....	14,490	12	360
Carbon steel	AD-6	Quenched and drawn	87,900	43,500	41,100	30	295
Carbon steel	AD-7	Quenched and drawn	69,600	36,400	34,000	25	180
Carbon steel	AD-1	Annealed	58,000	21,700	19,300	15	182
Nickel steel	Q-3	Quenched and drawn	67,920	....	45,880	37	360
Chrome-nickel steel	AK-4	Quenched and drawn	75,900	70,200	66,100	58	198
Chrome-nickel steel	AK-1	Annealed	74,100	31,200	28,800	29	221
Nickel, cold-rolled	CT	As received	81,500	58,000	36,200	75	550
Nickel, cold-rolled	CT-5.5	Annealed	85,600	58,000	50,700	120	623
Nickel, cold-rolled	CT-11	Annealed	73,400	*	*	*	710
Nickel, cold-rolled	A-16	Annealed	55,700	*	*	*	348
Monel metal, cold-rolled	BK-1	Annealed	67,900	*	*	*	634
Nickel-copper alloy	CU	As received	59,800	19,300	9,700	10	923
Constantan, cold-rolled	CV	As received	65,000	*	*	*	820
Constantan, cold-rolled	CV-14.5	Annealed	55,700	*	*	*	914
Copper, cold-drawn	CL	As received	31,000	*	*	*	759
Alpha copper-tin alloy, cold-drawn	CK	As received	50,700	*	*	*	618
Copper-nickel-zinc alloy, cold-drawn	CH	As received	48,450	*	*	*	533
Copper-zinc-nickel alloy, cold-drawn	CG	As received	51,600	29,000	14,500	20	637

* Stress-strain graph curved from origin.

TABLE 5 RELATIONSHIP OF ENDURANCE LIMITS TO OTHER PHYSICAL PROPERTIES
(Each value is average of two specimens except as indicated.)

(1) Material	(2) Material designation	(3) Heat treatment	(4) Average tensile strength, lb. per sq. in.	(5) Average torsional strength, lb. per sq. in.	(6) Average shearing strength, lb. per sq. in.	(7) Modulus of elasticity, lb. per sq. in.	(8) Endurance limit lb. per sq. in. rotating cantilever	(9) Static ratios Col. 5 to Col. 4	(10) Static ratios Col. 6 to Col. 4	(11) Endurance ratio Col. 8 to Col. 4
Carbon steel	O-3	Quenched and drawn	66,000	53,400	....	....	26,000	0.81	..	0.39
Carbon steel	O-5	Annealed	55,120	46,640	....	....	22,500	0.81	..	0.41
Carbon steel	AD-6	Quenched and drawn	115,000	87,850	....	....	49,500	0.76	..	0.43
Carbon steel	AD-7	Quenched and drawn	105,080	69,590	....	....	46,500	0.66	..	0.44
Carbon steel	AD-1	Annealed	75,000	57,960	....	....	35,000	0.77	..	0.47
Nickel steel	Q-3	Quenched and drawn	97,500	67,920	....	....	48,500	0.70	..	0.50
Chrome-nickel steel	AK-4	Quenched and drawn	127,800	75,880	....	....	66,500	0.59	..	0.52
Chrome-nickel steel	AK-1	Annealed	102,400	74,140	....	....	49,500	0.72	..	0.48
Nickel, cold-rolled	CT	As received	†115,800	*81,500	65,500	....	38,000	0.70	0.57	0.32
Nickel, cold-rolled	CT-5.5	Annealed	**113,900	*85,600	70,900	....	38,000	0.74	0.62	0.33
Nickel, cold-rolled	CT-11	Annealed	100,500	*73,400	65,400	....	36,500	0.73	0.65	0.36
Nickel, cold-rolled	A-16	Annealed	70,400	*55,700	50,400	....	25,500	0.79	0.72	0.36
Monel metal, cold-rolled	BK-1	Annealed	77,100	*67,900	55,300	....	26,000	0.88	0.72	0.33
Nickel-copper alloy	CU	As received	**65,400	*59,800	47,500	....	26,500	0.91	0.73	0.40
Constantan, cold-rolled	CV	As received	103,300	*65,000	59,400	....	43,000	0.63	0.58	0.42
Constantan, cold-rolled	CV-14.5	Annealed	69,400	*55,700	49,900	....	28,000	0.80	0.72	0.40
Copper, cold-drawn	CL	As received	40,400	*31,000	25,400	††16,600,000	12,500	0.77	0.63	0.31
Alpha copper-tin alloy, cold-drawn	CK	As received	62,900	*50,700	41,600	††20,000,000	27,000	0.81	0.66	0.43
Copper-nickel-zinc alloy, cold-drawn	CH	As received	62,400	48,450	40,900	....	22,000	0.78	0.66	0.35
Copper-zinc-nickel alloy, cold-drawn	CG	As received	58,700	51,600	40,000	....	17,000	0.88	0.68	0.29

* One determination only. ** Average of three determinations. † Average of seven determinations. †† One determination from 2-in.-gage-length specimen.

In a later bulletin[7] Moore and Jasper confirm the results obtained by the author on the torsion endurance range, but still hold to their conclusions that the bend endurance range decreases with departure from the middle of the elastic range. Since most of their results, however, were obtained with steels of low elastic ratio, it is hoped that they will make further experiments to determine definitely whether or not the constant-range relationship holds for a tension-compression or bend endurance range as it does for a torsion endurance range.

The fact that the torsion endurance range for steels is nearly independent of the position of the endurance range within the elastic range shows that there is an advantage in the use in shafting of material with a high elastic ratio. Although the endurance range of a metal depends chiefly on its tensile strength, with steel of high elastic ratio the position of the endurance range within the elastic range can be varied greatly. With steel of low elastic ratio, however, the full endurance range can be secured only with complete or nearly complete reversal of stress per cycle.

Endurance Properties of Non-Ferrous Metals

Investigation of the endurance properties of non-ferrous metals and alloys had not advanced far before it became evident that for such investigation individual endurance tests of only a few million cycles would not usually be sufficient. Stress-cycle graphs for non-ferrous metals do not usually become nearly horizontal at abscissas of one to ten million cycles as do stress-cycle graphs for steels.

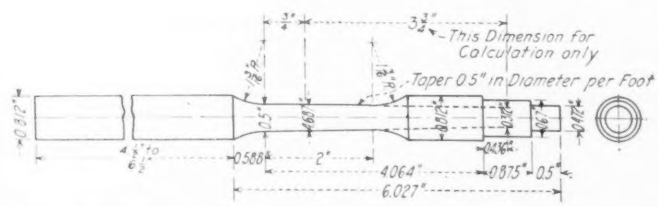

FIG. 8 ROTATING-CANTILEVER SPECIMEN USED IN ENDURANCE TESTS

This is illustrated by a comparison of the graphs for non-ferrous metals in Figs. 13 to 16,[15,16,17] inclusive, with the graphs for steels in Fig. 9 to 12, inclusive.

Fig. 13 shows results obtained with cold-rolled nickel, Materials CT and A. The upper graph in Fig. 13 shows results obtained with Material CT as received and with the same material after annealing at 550 deg. fahr. (Material CT-5.5). It will be observed that annealing at 550 deg. fahr. has not appreciably changed the endurance properties. The form of the average stress-cycle graph is similar to the form of the stress-cycle graphs for steels, Figs. 9 to 12. The stress-cycle graph for nickel, however, does not become practically horizontal before it reaches an abscissa of 50,000,000 cycles. The zigzag line with a small circle at the upper end represents the course of a single endurance test in which the specimen endured a stress of 38,000 lb. per sq. in. for about 60,000,000 cycles. The stress was then raised repeatedly by steps of 1000 lb. per sq. in. until finally the specimen broke at a stress of 47,000 lb. per sq. in. after enduring a total of nearly 100,000,000 cycles. Evidently this specimen would have endured many hundred million cycles at the original stress. Similar zigzag lines in following figures have similar significance.

The middle graph of Fig. 13 shows results obtained with the same material after annealing at 1100 deg. fahr. (Material CT-11). Its form is similar to that of the upper graph and the endurance limit

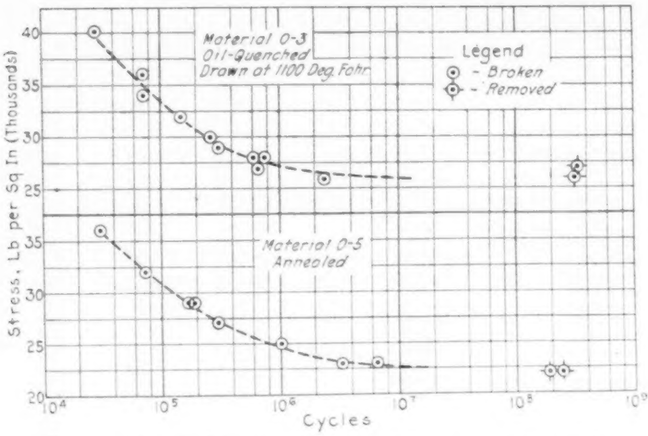

FIG. 9 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIAL O

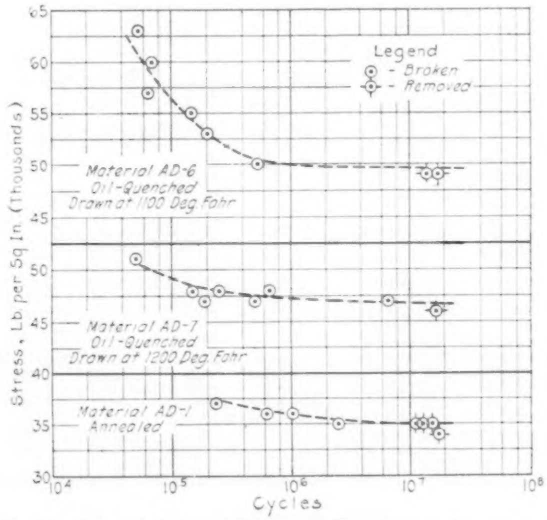

FIG. 10 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIAL AD

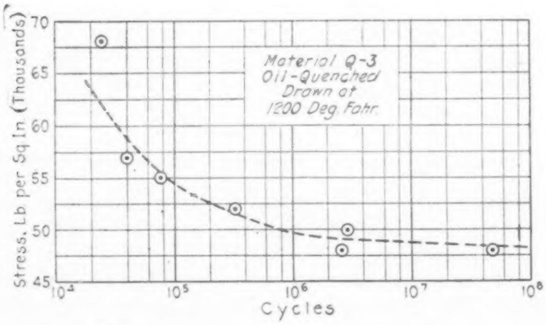

FIG. 11 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIAL Q

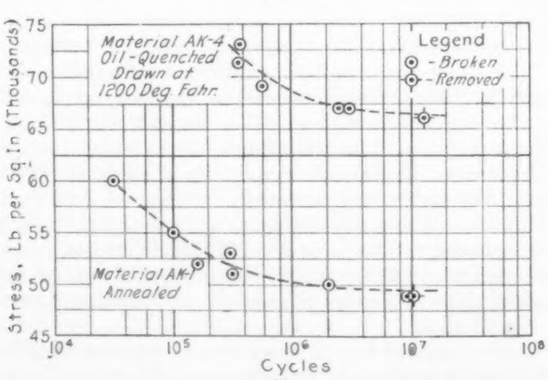

FIG. 12 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIAL AK

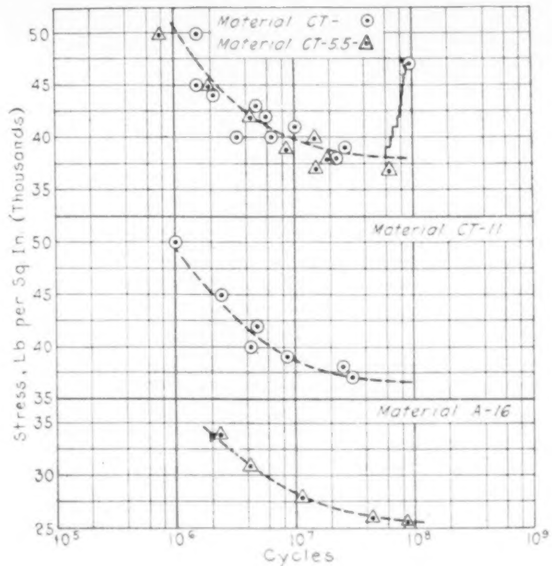

FIG. 13 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIALS CT AND A

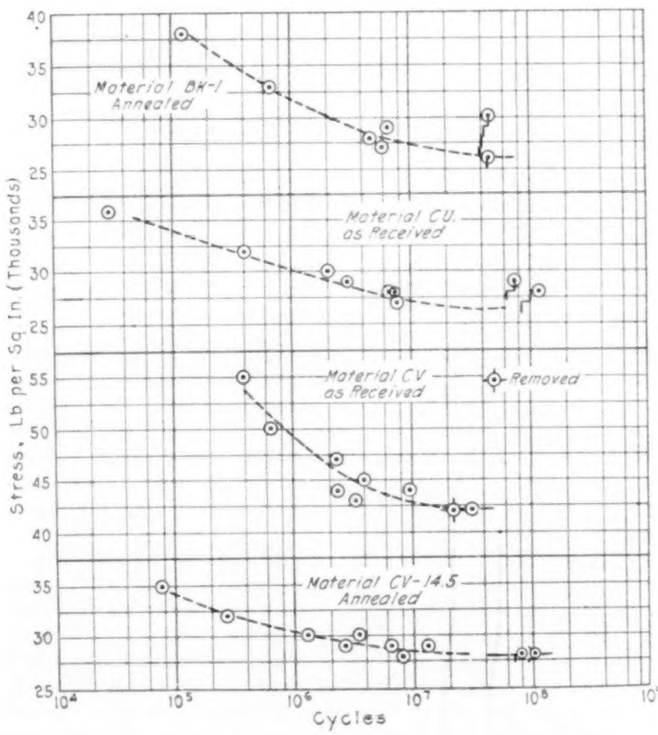

FIG. 14 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIALS BK-1, CU, AND CV

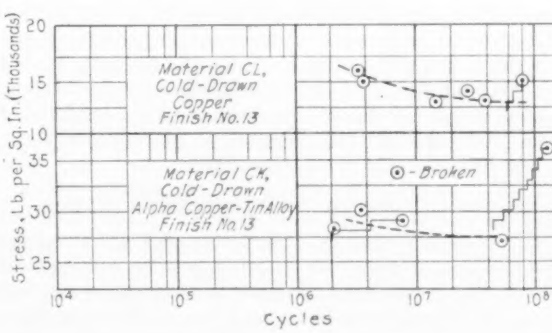

FIG. 15 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIALS CL AND CK

is practically the same, although, as shown in Table 3, the tensile strength is somewhat lower.

The lower graph in Fig. 13 shows results obtained with fully annealed nickel, Material A-16. Annealing at 1600 deg. fahr. has lowered the tensile strength and the endurance limit. The individual results coincide with a smooth curve that evidently becomes practically horizontal at an abscissa of 50,000,000 cycles, although there is apparently a very slight downward slope between abscissas of fifty and one hundred million cycles.

Fig. 14 shows results of endurance tests on three alloys of nickel and copper. The uppermost graph shows the endurance properties of cold-rolled and fully annealed monel metal. This graph evidently becomes practically horizontal at an abscissa of about 50,000,000 cycles. The next highest graph in Fig. 14 represents an alloy having about 55 per cent nickel and 45 per cent copper. This graph evidently becomes nearly horizontal at an abscissa of 50,000,000, and the slope is slight beyond an abscissa of 20,000,000.

The lower two graphs of Fig. 14 represent cold-rolled constantan (about 45 per cent nickel, 55 per cent copper). For Material CV (as received) the left-hand part of the graph is steeper than for Material CV-14.5 (annealed). Both of these graphs become nearly horizontal at abscissas of not more than 50,000,000. For the annealed material the slope of the graph beyond an abscissa of 10,000,000 cycles is very slight.

Fig. 15 illustrates endurance properties of cold-drawn copper and a cold-drawn copper-tin alloy. The graph for copper becomes nearly horizontal at an abscissa of about 20,000,000 cycles. The slope of the graph for the copper-tin alloy is evidently slight beyond about 10,000,000 cycles and the graph becomes practically horizontal beyond about 20,000,000 cycles. The endurance limit of the copper-tin alloy is about twice that of the copper.

Fig. 16 shows the endurance properties of two copper-nickel-zinc alloys (german silvers). The graphs for these ternary alloys are similar in form to those for metals and binary alloys. Each graph evidently becomes practically horizontal at an abscissa of not more than 50,000,000 cycles.

A comparison of the graphs for non-ferrous metals, Figs. 13 to 16, with the graphs for steels, Figs. 9 to 12, makes it evident that

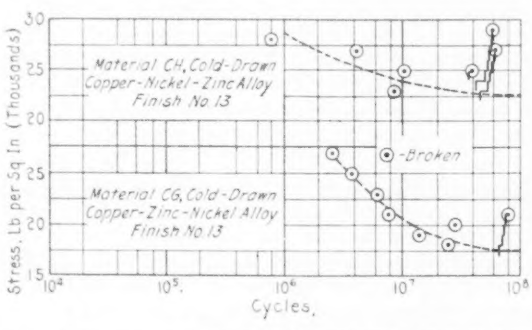

FIG. 16 GRAPHS SHOWING ROTATING-CANTILEVER RESULTS FOR MATERIALS CH AND CG

the form of the typical stress-cycle graph is the same for a non-ferrous as for a ferrous metal. The typical graph consists of a curve of gradually decreasing slope ending in a practically horizontal line. The abscissa at which the graph becomes practically horizontal varies from one to ten million cycles for steels and from about ten to fifty million cycles for non-ferrous metals. Investigation of a great variety of non-ferrous metals has not disclosed any metal the endurance limit of which cannot be determined by individual endurance tests of not more than 50,000,000 cycles. For some non-ferrous metals the stress-cycle graph evidently slopes slightly downward between abscissas of fifty and one hundred million cycles. When there is a slope between these abscissas, however, it is so slight that the ordinate does not vary more than about 2 per cent. Beyond an abscissa of 100,000,000 cycles, if there is any downward slope, it is so slight that it can be disregarded in the determination of practical endurance limits for non-ferrous metals.

EFFECT OF COLD-WORKING ON ENDURANCE PROPERTIES OF METALS

When metal is cold-rolled or cold-drawn the microstructure is altered as illustrated by a comparison of Figs. 1 and 2. At the same time the strength of the metal is increased and the ductility decreased. Until recently, however, the effect of cold-working on the endurance limit was not known. The author as a result of experiments described in a previous publication[16,17] recently determined that by moderate cold-working the rotating-cantilever endurance limit is increased in proportion to the increase in tensile strength. By severe cold-working, however, the endurance limit of nickel and probably of other metals is not increased in proportion to the increase in tensile strength. The boundary between "moderate" and "severe" cold-working for nickel is the degree of cold-working that will increase the tensile strength 40 or 50 per cent above that of fully annealed material. With increase of the degree of cold-working beyond this boundary the increase in the rotating-cantilever endurance limit is slight. The boundary between severe and moderate cold-working for other metals is being investigated.

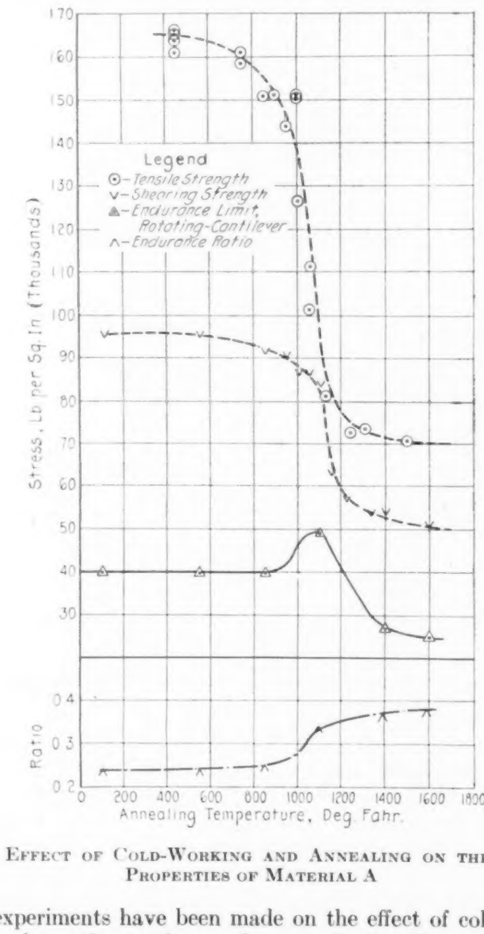

FIG. 17 EFFECT OF COLD-WORKING AND ANNEALING ON THE PHYSICAL PROPERTIES OF MATERIAL A

Few experiments have been made on the effect of cold-working on the alternating-torsion endurance limit. The experiments indicate, however, that the alternating-torsion endurance limit is only slightly increased by cold-working alone, though it is possible to increase it by cold-working and then annealing so as to produce incipient recrystallization.

EFFECT OF COLD-WORKING AND ANNEALING ON ENDURANCE AND OTHER PHYSICAL PROPERTIES

The effect on the microstructure caused by annealing cold-worked nickel at various temperatures is illustrated by Figs. 4 to 7, inclusive, and Fig. 1, and has been discussed. The effect of temperature of anneal on some physical properties of the same bar of nickel is illustrated by Fig. 17.[16,17] In this figure, abscissas represent temperature of anneal and ordinates represent various physical properties.

The uppermost graph in Fig. 17 represents the effect of temperature of anneal on the tensile strength. As illustrated by this graph, the downward slope of the curve increases with increase in temperature of anneal up to a temperature of about 1000 deg. fahr. Between 1000 and 1100 deg. the tensile strength decreases very rapidly. Above about 1100 deg. the slope of the curve decreases

rapidly, and above about 1200 deg. the slope is slight. The curve of shearing strength is similar in form to the curve of tensile strength, and the steepest part of the curve occurs at the same temperature range. The steepest part of these curves corresponds to the temperature range within which recrystallization occurs as illustrated by Figs. 4 to 7, inclusive.

The lower two graphs of Fig. 17 illustrate the effect of temperature of anneal on the rotating-cantilever endurance limit and on the ratio of endurance limit to tensile strength (endurance ratio). With increase in the temperature of anneal the endurance limit remains constant up to a temperature of 1000 to 1100 deg. fahr., the temperature of incipient recrystallization. At this temperature the endurance limit increases about 9000 lb. per sq. in., although the tensile strength has been considerably lowered. With further increase in temperature of anneal, the endurance limit decreases in proportion to the decrease in tensile strength. The endurance

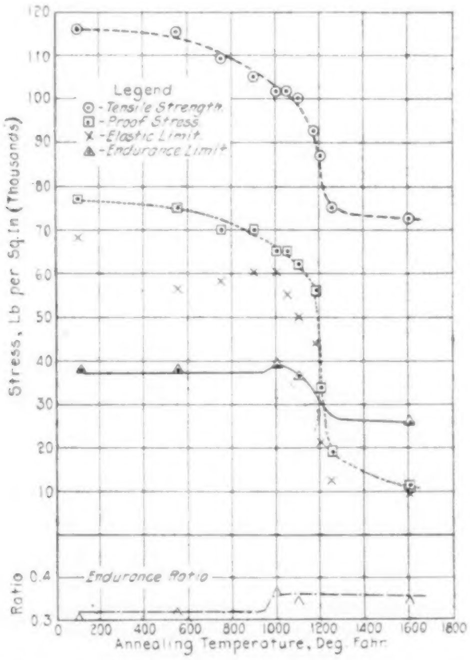

Fig. 18 Effect of Cold-Working and Annealing on the Physical Properties of Nickel Material CT

ratio at the temperature of incipient recrystallization increases abruptly nearly to the value for fully annealed nickel.

It should be noted that Material A, illustrated by Fig. 17, is severely cold-worked material. Its tensile strength is more than twice that of fully annealed material. As shown by the lower two graphs of Fig. 17, the endurance limit of the severely cold-rolled nickel has not been increased above that of fully annealed nickel in proportion to the increase in tensile strength.

Fig. 18[16,17] illustrates the effect of temperature of anneal on less severely cold-worked nickel, Material CT. The tensile strength of this cold-rolled nickel is about 60 per cent greater than that of fully annealed nickel. The uppermost graph of Fig. 18 shows the effect of temperature of anneal on tensile strength. The curve is similar to the curve of tensile strength for Material A, Fig. 17, except that the steepest part occurs at a somewhat higher temperature. In general, the temperature of the recrystallization range is lower the greater the degree of cold-working.

The curves of "proof stress" and "elastic limit" are similar in form to the curve of tensile strength. By "proof stress" is meant the stress that causes permanent elongation of 0.0002 in. on a 2-in. gage length. By "elastic limit" is meant the highest stress that causes no permanent deformation.

The rotating-cantilever endurance limit is unaffected by increase in the temperature of anneal until the temperature of incipient recrystallization (1000 deg. fahr.) is reached. At this temperature the endurance limit increases slightly, although the tensile strength has been somewhat lowered. Above this temperature the endurance limit decreases in proportion to the decrease in tensile strength. As shown by the lowest graph of Fig. 18, the endurance ratio at the temperature of incipient recrystallization rises abruptly to about the value for fully annealed nickel.

A comparison of Figs. 17 and 18 shows that the difference between the endurance ratio of nickel as rolled and nickel fully annealed is greater for Material A than for the less severely cold-worked Material CT. Numerous experiments on moderately cold-worked material have shown that the rotating-cantilever endurance ratio is not decreased by moderate cold-working.

In a recent paper,[17] graphs are shown illustrating the effect of degree of cold-working on the endurance properties of nickel. Investigation of the subject is being continued.

Influence of Chemical Composition on Endurance Properties of Metals

The influence of chemical composition and heat-treatment on the endurance properties of steel is too large a subject to be considered here. The influence of chemical composition on the endurance properties of alloys of nickel and of copper has recently been discussed by the author in a series of papers.[15,16,17] In order to estimate the effect of chemical composition of alloys it is necessary to make allowance for the effect of cold-working. This may be done by determining the endurance properties of alloys in the fully annealed condition or by calculating the endurance limits of fully annealed alloys from the endurance limits of moderately cold-worked alloys on the assumption that the endurance ratio of the alloy in both conditions is the same. In the above-mentioned papers a number of graphs are shown, in each of which the percentages of the two constituents of a binary alloy are plotted as abscissas and the endurance limits and other physical properties as ordinates. In this way all the common alloys of nickel and of copper have been represented. From these diagrams the composition best suited for endurance under various conditions has been selected.

Figs. 9 to 18, inclusive, represent results of investigation at the Naval Engineering Experiment Station. Some of the above-discussed figures are taken from previous papers to which reference has been made. Many of them, however, represent also the results of additional endurance tests. The author wishes to acknowledge the encouragement in this work received from Captain P. B. Dungan, U. S. N., Officer in Charge, United States Naval Engineering Experiment Station, and the assistance received from G. F. Wohlgemuth, associate metallurgist, and from J. L. Basil and A. P. Vandermast, laboratorians at the Naval Experiment Station.

Export of Engineering Talent from England

An editorial decrying the loss to England from the export of engineering talent. When the Huguenots were expelled from France, it says, England received a nucleus of highly skilled workmen which contributed as much as anything to the growth of Britain's industrial greatness. But for many years now Great Britain has been encouraging foreign manufactures by the free export of her talent in the form of skilled men and brains.

"Both German and American industry," continues the editorial, "rest largely on this foundation of British talent. As long as this was a free flow, and Great Britain was herself prosperous, there was little to be said against this natural and unavoidable movement; but now the conditions are greatly changed, and it is chiefly the adversity of economic conditions in this country which is forcing craftsmen and technical men to foreign lands. Thus, in the moment of adversity, we are forced to give succor to our most successful competitors, besides weakening our power of recuperation in the act.

"When this emigration is to other parts of the Empire, there is little to be regretted; but when we see Uncle Sam holding up glittering prizes to draw our best talent, then we must indeed, feel a sense of grave disadvantage. It is not long ago when Mr. Oliver Smalley took up an important position in the States; now, another eminent metallurgist, Mr. Kent Smith, O.B.E., follows in his steps.

"Contemporaneously with Mr. Kent Smith, goes Mr. Duckenfield; but the latter goes to Rhodesia, and will there continue to engage in the work of the Empire." (*The Metal Industry*, vol. 26, no. 17, Apr. 24, 1925, p. 419.)

Recent Developments in the Burning of Anthracite

By W. A. SHOUDY[1] and R. C. DENNY,[2] NEW YORK, N. Y.

The anthracite referred to is that of which at least 95 per cent will pass through a $^3/_{16}$-in. round-mesh screen and less than 20 per cent through a $^3/_{32}$-in. round-mesh screen. The coal is burned on Coxe stokers.

The paper describes successive furnace designs made at the Amsterdam (N. Y.) steam station of the Adirondack Power and Light Corporation. The boilers are of Babcock & Wilcox design and of 1345 hp. Each boiler has two Coxe stokers. Attempts were made to improve on the customary furnace design to which the following objections are made: (a) Tendency to stratification of gases, (b) high carbon content of ash, (c) loss of fines to ashpit and stack, and (d) lack of flexibility.

The first experimental furnace had, in addition to the ignition arch, a very short arch over the rear of the grate. With this arrangement improvement, if any, was slight. A three-arch furnace was then built, with better results but with defects due to slagging. A third furnace of two-arch design was finally constructed. Tests reported in the paper show that with the final design stratification can be practically eliminated, as well as ignition troubles, even with low-grade coal. A decided improvement has also been made in the burning of undersizes. The boilers and furnaces are described and illustrated, and results of tests are given in the form of curves.

Low volatile content and high fixed carbon give anthracite cleanliness and smokelessness, but at the same time make the coal difficult to ignite. In burning the smaller sizes, considerable difference in pressure must exist to force the air for combustion through the fuel bed and the coal must be fired frequently in a thin layer. The coarser sizes because of the larger air spaces, can be burned in a thick bed and fired only two or three times a day. These are therefore in great demand by the householder, which eliminates them, however, for large power requirements.

The crushing of the coal to bring it down to the domestic sizes produces a percentage of smaller sizes not in demand for household use. These sizes must be sold or the entire burden will be placed on users of the domestic sizes. Pea, No. 1 buckwheat, and No. 2 buckwheat can be utilized in large furnaces where greater draft can be obtained, either by higher chimneys or forced draft, but there still remains a percentage of the total, varying from 3 per cent to 10 per cent or more, that at present can only be used for power requirements. This coal is generally called No. 3 buckwheat, though sometimes "bird's-eye." The authors use as their specification the following sizing:

"Not less than 95 per cent to pass through a $^3/_{16}$-in. round-mesh screen and not over 20 per cent through a $^3/_{32}$-in. round-mesh screen."

They have called all larger than $^3/_{16}$ in., "oversize," and all smaller than $^3/_{32}$ in., "undersize."

The proper sizing of anthracite plays a prominent part in producing satisfactory boiler efficiencies. There are in general use only two satisfactory methods of burning this fuel, viz., by hand firing and by chain-grate stokers. However, pulverization promises a means of disposing of the "undersize."

The ignition difficulties with anthracite have made it necessary to employ a refractory arch to shield the ignition end of the furnace from the cooling of the boiler tubes. This is essential with the chain-grate stoker and useful with hand fires also, unless enough bituminous coal is mixed with the anthracite to supply the volatile constituent to support ignition. Fig. 1 illustrates this single-arch type of furnace, unusually high and with a large combustion volume, and grate extending under the full length of the furnace.

Objection to Former Design

Low efficiencies in this type of furnace (as compared with bituminous coal) were formerly accepted as inevitable. The objections to this type are:

a Tendency to stratification of gases
b High carbon content of ash
c Loss of fines (undersize) to ashpit and back connections
d Lack of flexibility.

Combustion on a chain grate is progressive. Ignition takes place at the front end and combustion extends over the center, with ash more or less completely burned at the rear. At the front there is generally found high CO, in the center high CO_2, and at the rear end considerable excess air. Unless these gases are well mixed, combustion is not complete. The alternative to operating with high excess air is high CO with its resultant loss.

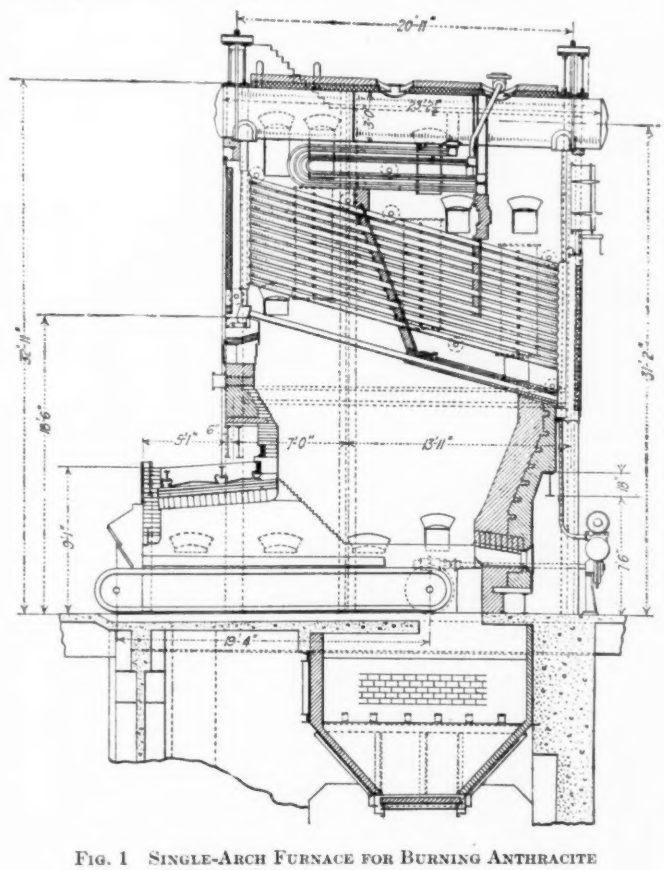

Fig. 1 Single-Arch Furnace for Burning Anthracite
(Original setting of boilers No. 1 and No. 2.)

Carbon cannot be completely burned from the ash without considerable excess air at the rear end; this excess air usually follows a well-defined lane throughout the setting. Again the operator is faced with the alternatives of reducing the stack loss by reducing the excess air, thereby increasing the carbon loss to the ashpit, or reducing the carbon loss and increasing the stack loss.

Lack of uniformity in the sizing of the fuel results in closing up the air passages through the fuel bed, requiring a higher pressure beneath the grate. The higher pressure breaks through the fire in spots and the air picks up the finer coal and throws the unburned carbon back into the ashpit, or the gases carry these fines through the setting and deposit them on the tubes, in the back connection, and in the breeching. Some are carried off through the stack. An examination of these particles shows that only their volatile content has been driven off. This is a direct loss.

With this type of furnace the length of the fire varies with the load, and thickness with the coal sizing. An increased load means lengthening the fire, and too rapid a change of speed tends to cause ignition troubles. Consequently if the load varies widely, the operator must carry a long fire and waste coal to the ashpit at light loads,

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or save this coal with shorter fires and take his chances on maintaining stream pressure.

The Experimental Furnace

For a number of years investigators have been studying this subject, and experiments with a second arch placed over the rear of the grate promised such satisfactory progress that the American Sugar Refining Company installed the boilers in its Baltimore refinery with a furnace embodying this principle. The authors' experiences with those furnaces convinced them that a distinct advance had been made.

The Amsterdam (N. Y.) Steam Station of the Adirondack Power and Light Corporation was started in October, 1921, with one 15,000-kw. turbine and two 1345-hp. boilers. The boilers are

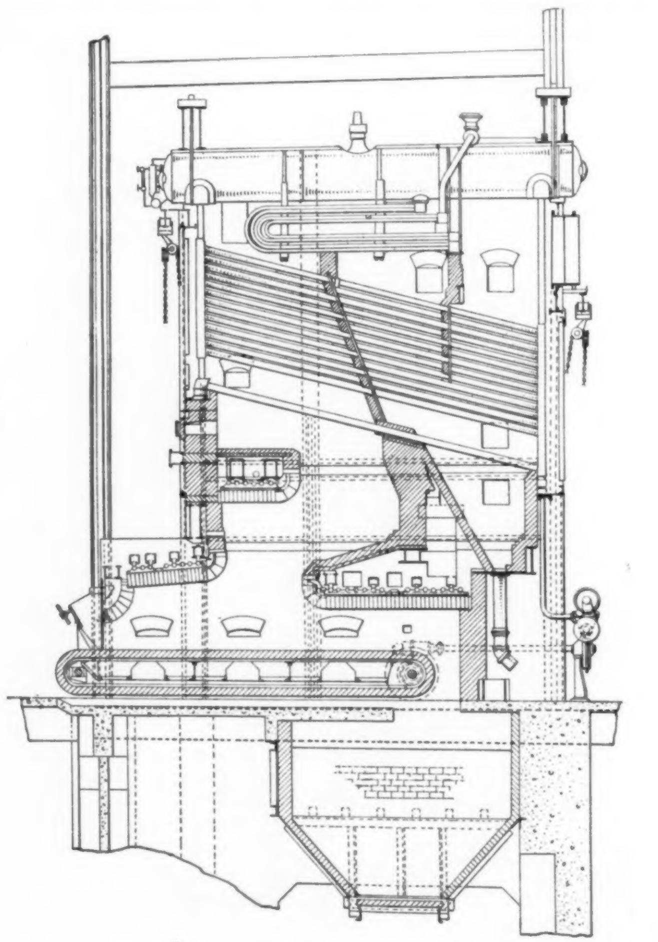


Fig. 2 Triple-Arch Experimental Furnace (Boiler No. 1) at Amsterdam

of Babcock & Wilcox design, 42 tubes wide and 14 tubes high, with 20-ft. tubes. Each boiler is set with two Coxe traveling-grate stokers 10 ft. $8^5/_8$ in. wide by 17 ft. long (effective grate length). The load is extremely variable, and some difficulty was experienced in operating with but two boilers. Experience elsewhere with multi-arch furnaces being so satisfactory, an appropriation was authorized for the construction of an experimental furnace with triple arch, and boiler No. 1 (Fig. 1) was used with this furnace shown in Fig. 2. An extended series of tests was made of this experimental furnace and also of boiler No. 2 with the old furnace shown in Fig. 1. Six tests with the new furnace and three with the old furnace are presented in Table 1 and Figs. 3 and 4.

The new furnace proved more than satisfactory from a combustion standpoint. One operating difficulty made it necessary to redesign it to make it entirely satisfactory, namely, the accumulation of a mixture of carbon and slag on the rear arch. The slag was deposited in a plastic state, and in about three weeks' continuous operation so restricted the throat that the boiler had to

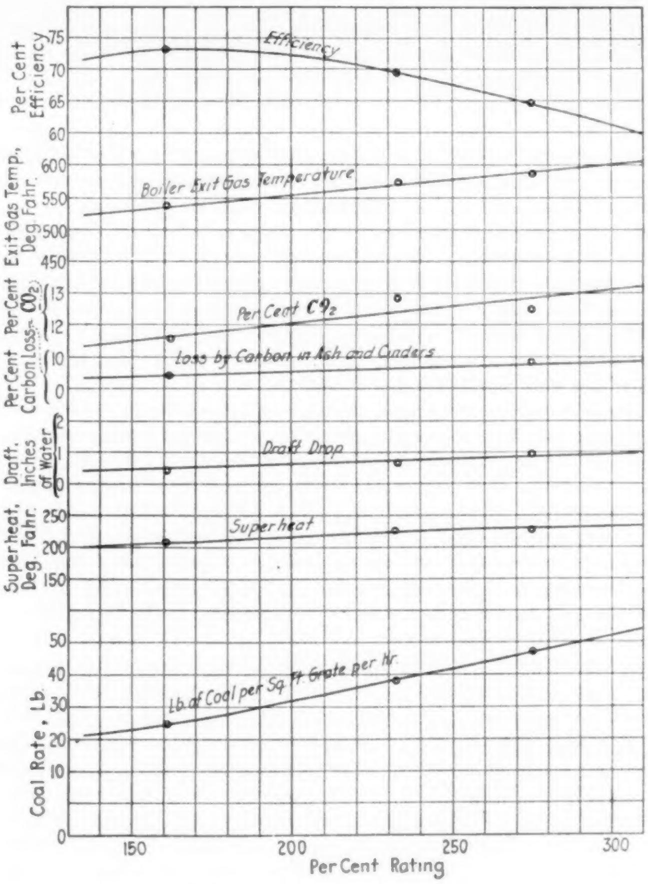


Fig. 3 Test Results with Single-Arch Furnace

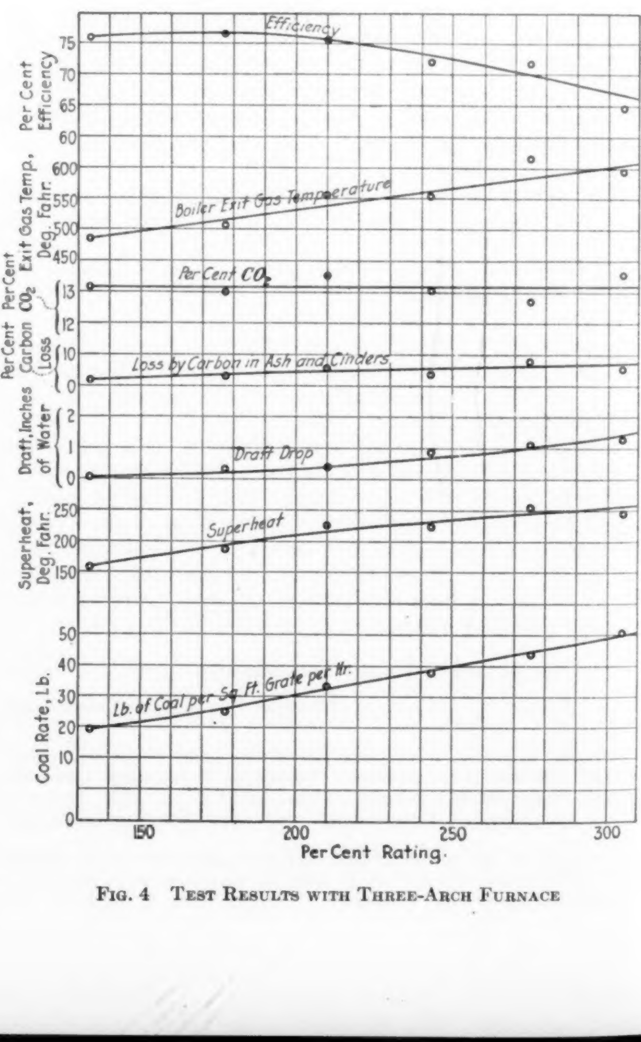


Fig. 4 Test Results with Three-Arch Furnace

TABLE 1 DATA AND RESULTS OF EVAPORATIVE TESTS

Test number		1	2	3	4	5	6	7	8	9	21	22	23	24	26	27
Boiler number		1	1	1	1	1	1	2	2	2	2	2	2	2	2	2
Grate surface,	sq. ft.	364	364	364	364	364	364	364	364	364	364	364	364	364	364	364
Water-heating surface,	sq. ft.	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450	13,450
Superheating surface,	sq. ft.	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863	3,863
Total heating surface,	sq. ft.	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313	17,313
Ratio water heating to grate surf.		37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1	37-1
Ratio total heating to grate surf.		47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1	47.6-1
Volume of combustion chamber,	cu. ft.	2,690	2,690	2,690	2,690	2,690	2,690	6,140	6,140	6,140	....	....	......	......	......	......
Date		9/24/23	8/17/23	9/25/23	8/17-18/23	9/26/23	8/18-19/23	8/24/23	8/25/23	8/25-26/23	9/23/24	9/3/24	9/4/24	9/5/24	11/11/24	11/12/24
Duration,	hr.	8	8	8	9	8	9	8	8	8	8	8	8	8	8	8
Coal (anthracite):																
Oversize,	per cent	13.2	26.32	13.3	22.22	13.6	25.0	25.7	32.06	31.70	17.6	19.0	14.7	13.6	14.8	14.6
No. 3 Buckwheat,	per cent	51.2	57.87	50.5	59.28	59.3	60.0	48.6	41.52	46.34	48.5	49.7	48.0	46.0	52.0	52.6
Undersize,	per cent	35.6	15.81	36.2	18.50	27.1	15.0	25.7	26.42	21.96	33.9	31.3	37.3	40.4	33.2	32.8
Steam pressure by gage,	lb. per sq. in.	272.5	279.8	265.9	272.0	274.1	285.4	267.0	271.7	271.7	286.0	281.1	285.6	284.6	273	272
Barometer,	in. mercury	30.0	29.9	30.0	29.9	30.0	29.8	29.9	29.8	29.9	29.9	29.9	29.8	29.5	30.0	30.0
Steam temperature,	deg. fahr.	660	672	637	638	604	577	641	641	620	650	629	605	602	669	669
Saturated steam temperature,	deg. fahr.	413.6	415.8	411.5	413.4	414.4	417.5	411.8	412.9	412.9	417.8	416.2	417.8	417.8	414	413
Boiler-feed temperature,	deg. fahr.	164.0	146.4	154.0	156.3	152.0	156.3	141.0	146.0	145.0	185.0	191.0	190.0	197.0	180	179
Flue-gas temperature,	deg. fahr.	593	616	555	557	508	488	585	572	536	548	537	505	490	506	512
Draft betw. damper and boiler,	in. H_2O	1.30	1.16	0.90	0.38	......	0.09	0.97	0.67	0.48	1.13	0.94	0.80	0.79	0.255	0.194
Draft in main flue,	in. H_2O	2.61	1.60	1.24	1.05	0.32	0.50	1.80	1.42	1.72	1.50	0.95	1.37	1.42	0.370	0.470
Draft in furnace,	in. H_2O	0.00	−0.02	−0.01	0.00	+0.03	0.00	+0.01	−0.01	0.00	0.00	−0.026	−0.025	−0.135	+0.009	+0.020
External air temperature,	deg. fahr.	70	68	69	62	67	65	58	63	55	58	64	60	60	40	39
Entering air temperature	deg. fahr.	88	86	82	75	79	91	82	85	78	83	82	82	80	40	39
Superheat,	deg. fahr.	264.4	256.2	225.5	224.6	189.6	159.5	229.2	228.1	207.1	232.2	212.8	187.2	184.2	255	256
Total coal as fired,	lb.	148,021	129,227	108,000	107,736	74,022	62,895	137,524	111,341	72,404	154,489	144,796	107,409	82,738	69,572	63,046
Moisture as fired,	per cent	8.51	11.85	9.40	11.24	9.69	10.15	10.26	10.97	10.68	9.55	10.20	9.83	10.44	9.04	9.62
Total dry coal,	lb.	135,400	113,900	97,900	95,600	66,900	56,500	123,400	99,100	64,700	139,800	130,000	96,800	74,200	63,286	56,990
Ash from ashpit,	lb.	30,750	25,900	20,100	21,470	13,420	8,530	30,900	20,900	11,800	39,500	30,600	21,800	15,700	12,160	10,240
Cinders caught,	lb.	2,096	1,802	1,072	445	223	191	......	......	......	....	....	......	......	......	......
Total refuse,	lb.	32,846	27,702	21,172	21,915	13,643	8,721	30,900	20,900	11,800	39,500	30,600	21,800	15,700	12,160	10,240
Total combustible burned,	lb.	102,554	86,198	76,728	73,685	53,257	47,779	92,500	78,200	52,900	100,300	99,400	75,000	58,500	57,412	52,806
Total refuse based on dry coal,	per cent	24.2	24.3	21.6	22.9	20.4	15.4	25.0	21.1	18.2	28.2	23.5	22.5	21.2	19.2	18.0
Total water fed,	lb.	889,610	798,300	722,115	703,605	525,470	461,555	772,930	685,315	481,305	903,394	844,892	722,237	555,660	480,084	436,984
Factor of evaporation		1.253	1.277	1.251	1.249	1.252	1.213	1.267	1.261	1.246	1.225	1.205	1.194	1.185	1.242	1.243
Total equiv. water fed,	lb.	1,115,000	1,020,000	903,500	879,000	658,000	560,000	979,500	864,000	599,500	1,107,000	1,018,000	862,000	658,000	596,000	544,000
Dry coal per hour,	lb.	16,940	14,250	12,230	10,610	8,355	6,280	15,400	12,400	8,090	17,470	16,250	12,105	9,260	7,911	7,124
Dry coal per sq. ft. grate per hr.,	lb.	46.5	39.1	33.6	29.1	23.0	17.3	42.3	34.1	22.2	48.0	44.7	33.3	25.4	21.7	19.6
Water evap. per hr. corr. for quality,	lb.	111,201	997,888	90,264	78,178	65,684	51,284	96,616	85,664	60,163	112,924	105,612	90,279	69,458	60,011	54,623
Equiv. evap. per hour,	lb.	139,400	127,500	112,850	97,660	82,280	62,220	122,500	108,100	74,950	137,200	127,250	107,800	82,300	74,534	67,896
Equiv. evap. per hr. per sq. ft. h. s.,	lb.	10.37	9.48	8.39	7.26	6.12	4.63	9.11	8.04	5.57	10.2	9.47	8.02	6.12	5.55	5.05
Equiv. evaporation per hour,	lb.	139,400	127,500	112,850	97,660	82,280	62,220	114,500	108,100	749,500	137,200	127,250	107,800	82,300	74,534	67,896
Boiler hp. developed,	hp.	4,042	3,695	3,271	2,828	2,385	1,804	3,420	3,135	2,240	3,975	3,690	3,125	2,386	2,160	1,968
Rated boiler hp.	hp.	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345
Percentage of rating developed,		300.5	275.0	243.1	210.0	177.4	134.0	254.0	233.0	161.0	295.0	274.0	232.0	177.0	161	147
Water fed per lb. coal as fired,	lb.	6.01	6.18	6.69	6.53	7.10	7.34	5.25	6.15	6.65	5.85	5.84	6.72	6.72	6.91	6.93
Water evap. per lb. dry coal,	lb.	6.57	7.01	7.37	7.35	7.86	8.17	5.85	6.91	7.43	6.47	6.49	7.46	7.50	7.58	7.68
Equiv. evap. per lb. coal as fired,	lb.	7.54	7.89	8.36	8.15	8.90	8.90	6.65	7.75	8.28	7.17	7.03	8.02	7.95	8.57	8.63
Equiv. evap. per lb. dry coal,	lb.	8.23	8.94	9.22	9.20	9.85	9.90	7.36	8.72	9.28	7.85	7.83	8.91	8.89	9.42	9.55
Equiv. evap. per lb. combustible,	lb.	10.87	10.62	11.77	11.92	12.35	11.72	9.90	11.04	11.33	11.02	10.2	11.5	11.3	10.38	10.28
Heat value per lb. dry coal (calc.)	B.t.u.	12,370	12,110	12,400	12,155	12,470	12,630	11,932	12,175	12,310	12,260	11,850	11,675	11,265	12,084	12,095
Efficiency—boiler—grate—furnace	per cent	64.6	71.6	72.1	73.5	76.7	76.0	64.5	69.5	73.2	62.2	64.2	74.0	76.6	75.6	76.6
Average fire thickness,	in.	4.4	4.6	5.5	4.8	4.6	3.9	4.5	4.5	4.4	5.0	4.5	4.5	4.5	4.5	4.25
Stoker speed,	ft. per hr.	44.3	36.7	31.7	29.8	21.2	18.9	40.5	33.0	21.6	44.8	41.0	30.3	24.5	20.7	19.7
Flue gas																
Carbon dioxide,	per cent	13.56	12.77	13.08	13.56	13.00	13.14	12.48	12.80	11.58	11.30	13.60	12.50	11.4	13.1	13.5
Oxygen,	per cent	6.10	5.81	6.80	5.73	6.58	6.34	6.34	6.08	7.62	7.67	5.27	7.05	8.0	6.3	6.5
Carbon monoxide,	per cent	0.00	0.02	0.00	0.23	0.00	0.06	0.23	0.45	0.07	0.69	1.23	0.00	0.0	0.16	0.0
Nitrogen,	per cent	80.34	81.40	80.12	80.48	80.42	80.46	80.95	80.67	80.73	80.34	79.90	80.45	80.6	80.44	80.0
Proximate analysis																
Moisture,	per cent	8.51	11.85	9.40	11.24	9.69	10.15	10.26	10.97	10.68	9.55	10.20	9.83	10.44	9.04	9.62
Volatile matter,	per cent	8.07	6.22	6.58	5.67	5.98	5.62	6.20	6.18	6.17	8.16	7.44	6.93	5.91	7.36	7.30
Fixed carbon,	per cent	65.77	66.26	67.55	66.44	68.48	71.95	67.02	67.62	69.97	66.63	65.91	67.20	66.68	67.04	67.64
Ash,	per cent	17.65	15.67	16.47	16.65	15.85	12.28	16.52	15.23	13.18	15.66	16.45	16.04	16.97	16.56	15.44
Sulphur (dry basis),	per cent	0.73	1.24	0.54	1.05	0.34	0.75	0.69	0.63	0.72	0.56	0.69	0.59	0.74	0.51	0.61
Ultimate analysis (calculated)																
Carbon,	per cent	73.09	75.52	75.32	74.69	76.55	79.57	74.93	76.11	78.42	75.97	75.05	75.58	74.59	74.86	75.92
Hydrogen,	per cent	2.99	2.55	2.73	2.36	2.61	2.44	2.54	2.52	2.47	2.76	2.97	2.76	2.60	2.74	2.79
Oxygen,	per cent	3.27	2.08	2.73	2.35	2.49	2.73	2.60	2.79	2.78	2.88	2.07	2.38	2.65	2.79	2.69
Nitrogen,	per cent	0.62	0.84	0.51	0.80	0.46	0.84	0.84	0.84	0.85	0.51	0.92	0.89	0.46	0.88	0.89
Sulphur	per cent	0.73	1.24	0.54	1.05	0.34	0.75	0.69	0.63	0.72	0.56	0.69	0.59	0.74	0.51	0.61
Ash,	per cent	19.30	17.77	18.17	18.75	17.55	13.67	18.40	17.11	14.76	17.32	18.30	17.80	18.96	18.22	17.10
Ash analysis																
Volatile matter + carbon,	per cent	15.00	21.85	11.45	16.50	12.50	9.55	26.40	18.85	19.15	32.30	22.25	21.00	10.53	5.10	4.82
Earthy matter,	per cent	85.00	78.15	88.55	83.50	87.50	90.45	73.60	81.15	80.85	67.70	77.75	79.00	89.47	94.90	95.18
								HEAT BALANCE—DRY BASIS								
Heat absorbed by boiler,	per cent	64.60	71.60	72.10	73.50	76.70	76.00	64.5	69.50	73.20	62.20	64.20	74.00	76.60	75.6	76.6
Loss due to moisture in coal,	per cent	0.88	1.30	0.96	1.20	0.97	0.70	1.10	1.10	1.10	1.10	1.20	1.20	1.30	1.1	1.1
Loss due hydrogen burned,	per cent	2.77	2.50	2.50	2.20	2.34	2.10	2.40	2.40	2.30	2.60	2.80	2.60	2.60	2.6	2.7
Loss due to flue gases,	per cent	12.55	14.00	12.74	12.30	11.84	11.30	13.70	13.20	14.50	13.00	11.00	12.50	14.00	8.3	8.4
Loss due to carbon monoxide,	per cent	0.00	0.10	0.00	1.20	0.00	0.30	0.90	1.80	0.30	3.20	5.00	0.00	0.00	0.8	0.0
Loss due to combustible in ash,	per cent	4.01	6.00	2.77	4.40	2.96	1.70	*8.10	*4.80	*4.20	*9.80	*6.50	*5.90	*2.90	*1.2	*1.1
Loss due to carbon in cinders,	per cent	1.60	1.70	1.13	0.50	0.35	0.30	......	......	......	....	....	......	......	......	......
Unaccounted for,	per cent	13.59	2.80	7.64	4.70	4.84	7.00	9.00	7.20	4.40	8.10	9.30	3.80	2.60	10.4	10.1
Total,	per cent	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Includes cinder loss

be taken out for cleaning. This experience pointed the way to what appears to be the solution of the problem.

AN IMPROVED DESIGN

During this periodic building up of the slag it was found that there was little increase in draft drop with the reduction in gas passage. This deposit was allowed to accumulate until the opening between the upper arch and the slag was reduced to about a foot. Under this condition the boiler was operated at 240 per cent of rating (measured by flow meter) with an increased draft drop of only 0.2 in. of water.

This experience pointed to the possibility of obtaining complete mixing of the gases by using a restricted throat, and boiler No. 2 was reset with a restricted gas passage and applied to a third furnace of the two-arch type. The boiler has been operated intermittently since, but without operating difficulties.

IMPROVEMENT IN EFFICIENCY

Six tests of this boiler are included, the principal results being plotted in Fig. 5. The combined efficiencies at ratings below 250 per cent check very closely with the tests of the three-arch furnace. The two tests at higher ratings show a marked falling off in efficiency. It was difficult to regulate combustion conditions at ratings below 170 per cent because of the very low rate of com-

bustion. The two tests below this rating show high efficiency, but with a rather large unaccounted-for loss. They also show high superheat and high exit-gas temperatures. Only traces of CO were found, but probably some secondary combustion was taking place, since the low velocity of the gases undoubtedly made possible some stratification. These boilers are taken off the line at ratings below 170 per cent, and operated above 250 per cent rating only during emergency, but modifications in design will have to be made for boilers operated outside this range.

The combined efficiency curves of the three furnaces are shown in Fig. 6 and illustrate improvement obtained. The point of maximum efficiency for all furnaces is at about 170 per cent of rating, but the curves of the multiple-arch furnaces are flatter. The boilers, apparatus, and tests are described in an appendix to the complete paper. The principal data and results are given in Table 1.

The reasons for the improvement in efficiency are apparent from the analyses of the flue gases taken on the three-arch furnace and plotted in Figs. 7, 8, and 9.

The influence on combustion of the three arches in the furnace is exhibited in Fig. 7. Samples were taken through a water-cooled sampling tube about 12 in. over the fire and about 30 in. from the side wall. The lower set of curves on this chart shows the 17-ft. length of grate and the various points at which gas samples were drawn. In general, these gas samples represent the products of combustion over the several air compartments of the stoker. The boiler was run at about 275 per cent of rating.

For any ratings above 200 per cent some air is used in the first five stoker compartments, but none is admitted to the sixth compartment. Due to burning, the fuel bed decreases in thickness from the front of the stoker in a practically uniform slope down toward the rear. Air was admitted, not to secure any particular arrangements of draft readings by gage, but to burn the various sections of the fire in what seemed to be the most sensible manner.

As soon as the six analyses were made of the gas over the fire, the second set of five analyses was made in the bottom part of the first pass. The water-cooled tube was also used for this purpose. The location was not in the top of the combustion chamber just under the tubes but between the second and third row of tubes from the bottom, since that was the only place in which the sampling pipe could be introduced. As soon as these analyses were finished a set of six samples were drawn from the top of the third pass by means of one of the regular gas-sampling tubes.

These three sets of readings are in practically the same vertical plane through the setting and at practically identical firing conditions.

Over the first four air compartments the fire is to some extent a gas producer. Contrary to the usual notion, there is only a moderate amount of CO produced over the first compartment, the figure being about 6 per cent. The CO_2 at this same point is a little over 14 per cent. The CO increases up to nearly 12 per cent over the third compartment, whereas the CO_2 decreases to about 7 per cent until the fifth compartment is reached. Here excess air is always admitted. This of course comes from the operation of burning out of the fuel bed to form a reasonably clear ash. There is much less carbon burned over this compartment in proportion to the air blown through the fire. The CO_2 does not increase, but the free oxygen increases to about 12 per cent and the CO disappears entirely. Over the sixth compartment neither CO nor CO_2 is present in any appreciable quantity, the analyses showing practically pure air. The quantity represented by this last analysis is probably rather small since there is no direct air pressure in the sixth compartment.

The foregoing gas analyses are from a point about 12 in. above the fuel bed. Inspection of the curves in Fig. 7 for the analyses at the bottom of the first pass shows that combustion is practically complete. The CO has been nearly all burned out and there is very little free oxygen present except in the section of the pass nearest the baffle. The presence of this oxygen at this point shows that stratification has apparently followed through the tortuous path of gas travel which the arches compel. The CO_2 at nearly all points in the first pass is above 16 per cent, dropping down to about 14 per cent near the baffle. The indications from these figures are that a practically minimum amount of excess air has been used on this longitudinal section of the fire.

The curve of gas analyses at the top of the third pass shows substantially the same CO_2 but a uniformly low amount of CO. The free oxygen, amounting to around 2 per cent, is considerably higher at this point than it was at the bottom of the first pass, indicating air leakage into the setting between the two points.

The curves of Fig. 8 show a comparison of gas analyses over the fire at three different ratings. The difference between the full lines and the dotted lines, both of which are for about 275 per cent of rating, results from a difference in handling the fire on two

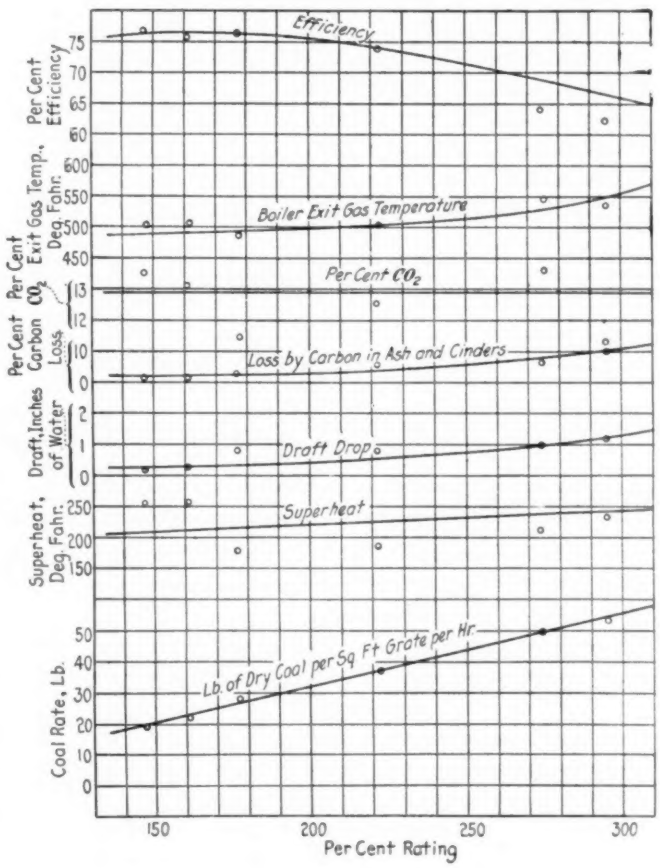


Fig. 5 Test Results with Two-Arch Furnace

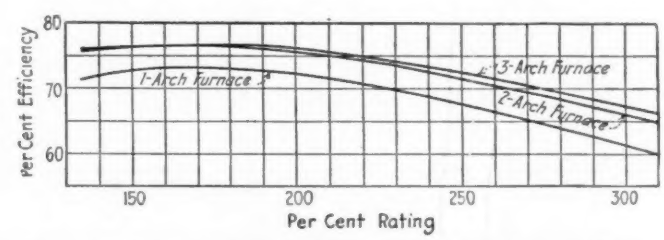


Fig. 6 Curves Comparing Efficiencies Obtained with Three Types of Furnaces

different days. The dotted lines are the same curves that were studied in Fig. 7. In handling the fire on August 17 somewhat higher air pressures were carried on the second and third air compartments. This lowered the CO_2 over these compartments and increased the percentage of oxygen, but it greatly reduced the amount of CO over the third compartment. At the fourth compartment the air pressure was carried a little lower than in the other run and the excess air dropped down nearly to zero, while the CO_2 rose abnormally to over 16 per cent. Over No. 5 compartment there is a characteristic disappearance of the CO and a great increase in the free oxygen. Over the sixth compartment the results on all runs show substantially the same character of gas.

The low-rating run shown by the dot-and-dash line was made with much less air pressure under all the compartments. The penetration of the air through the fire was considerably less than in the high-rating runs, and the curves show exactly what might

be expected. The CO rises from about $7^1/_2$ per cent over the first compartment to about 17 per cent over the fourth compartment, after which it drops off to zero. There is practically no free oxygen anywhere in the fire except over the fifth and sixth compartments. The CO_2 runs a little less in the forward part of the fire, increases to 12 per cent over the fifth compartment, and then drops off to zero over the sixth compartment.

"Cross-Sectioning" Exit Gases

The arrangement of gas-sampling tubes and thermocouples

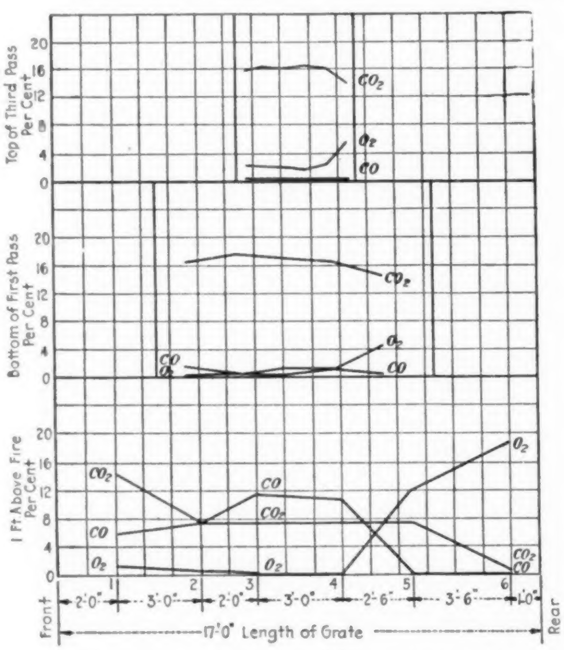


FIG. 7 VARIATIONS OF FLUE-GAS COMPOSITION IN THREE-ARCH FURNACE
(Special run, Aug. 21, 1923, 275 per cent rating.)

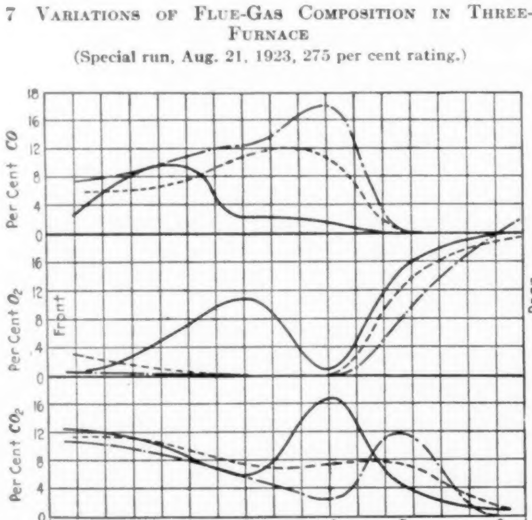


FIG. 8 VARIATIONS OF FLUE-GAS COMPOSITION OVER FIRE IN THREE-ARCH FURNACE
Full lines—274 per cent rating, Aug. 17, 1923
Dotted lines—275 per cent rating, Aug. 21, 1923
Dot-and-dash lines—134 per cent rating, Aug. 19, 1923

for ascertaining the character of the exit gases in the top of the third pass of No. 1 boiler are fully described in an appendix to the complete paper. It proved feasible to cross-section this area thoroughly with the thermocouples because the readings could be taken with the potentiometer almost instantaneously. It was also found possible to get a fair average of seven simultaneous gas samples across the setting. During one of the tests seven samples were analyzed independently with results shown in the lower part of Fig. 9.

It should be remembered that there are two stokers, with a three-foot center wall extending across the setting. That there is a serious amount of longitudinal stratification of gases is evidenced by the shape of the curve. Not only at this 134 per cent rating, but at various other ratings, the low CO_2 at the two end pipes was frequently remarked. Had single gas-sampling tubes been used, extending in from either side to about the center of each stoker, the CO_2 recorded for the entire series of No. 1 boiler would have been in the neighborhood of 16 per cent. The evidence of this cross-analysis is that such a reading would be seriously misleading.

The curves on the upper part of Fig. 9 are the individual temperature readings across the setting at various ratings. These show the same characteristic shape as the CO_2 curve.

Conclusion

That stratification can be practically eliminated and carbon loss to the ashpit reduced to a minimum, is shown clearly by the tests. Another accomplishment is the elimination of ignition troubles, even with low-grade coal. A decided improvement has been made in the burning of undersize at moderate ratings, but there is room for improvement at ratings above 250 per cent.

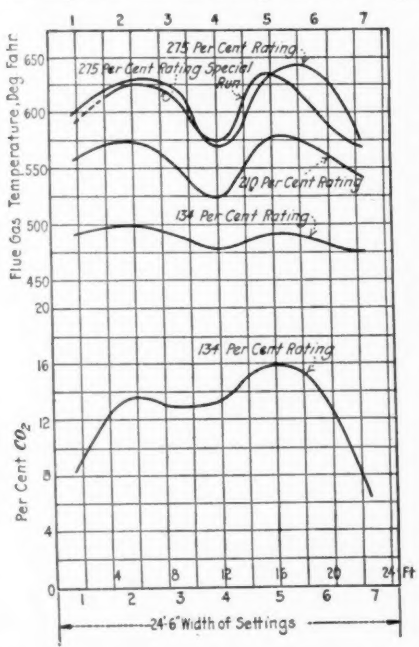


FIG. 9 TEMPERATURE AND CO_2 ACROSS TOP OF THIRD PASS OF THREE-ARCH FURNACE

All the tests were made with substantially the same quality of coal. There has not been time to conduct a series of tests with coal containing larger percentages of undersize, but operation has been studied with varying qualities running down to river coal with over 60 per cent undersize and 33 per cent ash. The maximum rating obtainable with the latter coal and the single-arch furnace was about 190 per cent, but with the two-arch furnace and the same coal 300 per cent rating can be carried without difficulty.

The loss in efficiency with increasing undersize has been estimated from the variations in coal per kilowatt-hour, and there is no doubt that the loss is less with the new type of furnace, particularly at the usual operating ratings of about 225 per cent. The development of these multiple-arch furnaces may help in the ultimate solution of the problem of burning undersize.

Discussion

A. R. MUMFORD[1] submitted a written discussion in which he presented evidence, independently collected and interpreted, which he believed completely substantiated the conclusions of the authors. The authors had pointed out that with the former standard design of furnace the operator had the alternative of reducing the stack loss by reducing the excess air, thereby increasing the carbon loss to the ashpit, or of reducing the carbon loss and increasing the stack loss. This condition was shown by Fig. 10, in which were plotted two sets of gas analyses which showed the effect on the furnace gases of increased air pressure in the last compartment.

In this and in Fig. 12 the full lines represented the percentage of CO_2, the long dash line the percentage of O_2, and the short dash line the percentage of CO. The samples had been collected simultaneously from all points shown by means of water-cooled sampling tubes whose open ends were over the center line of the stoker. The samples had been kept in glass bottles under water pressure until analyzed in a water Orsat.

The gas temperatures given on the charts were the averages of

[1] Fuel Engr., N. Y. Steam Corpn., New York, N. Y. Assoc-Mem. A.S.M.E.

the readings of five copper-constantan thermocouples read at 5-min. intervals during the 20-min. sampling period. The high temperatures shown were due to leaky baffles.

As indicated by the rapid fall of the first-pass CO_2 curve near the bridgewall, it was seen that the air passing through the thin rear end of the fuel bed rose directly to the first pass and thence traveled through the boiler. The condition under normal operation was shown by the light lines, while the heavy lines indicated the conditions with higher rear-end air pressure.

The effect of the rear or reversing arch was shown in Fig. 11. Here the heavy lines represented the gas composition with the reversing arch installed, while the light lines represented the gas composition without the added arch. Three points stood out rather clearly: First, the larger percentage of oxygen rising from the fuel bed at the rear indicated a thinner and consequently a more completely burned fuel bed at this point; second, the almost complete elimination of CO in the gases entering the first pass showed that the additional air had not increased the excess air

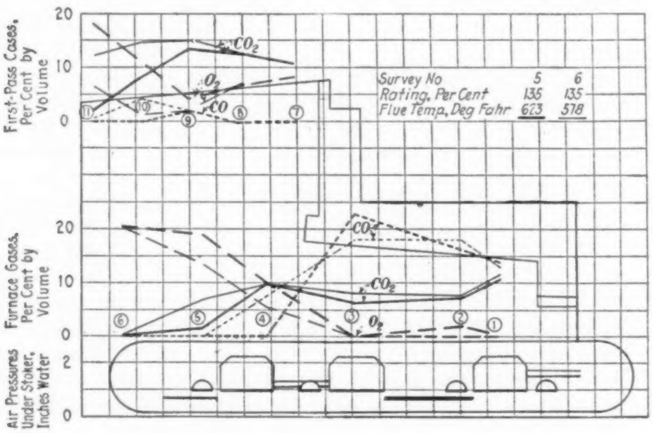


Fig. 10 Effect of Increasing Air Pressure in Last Air Chamber

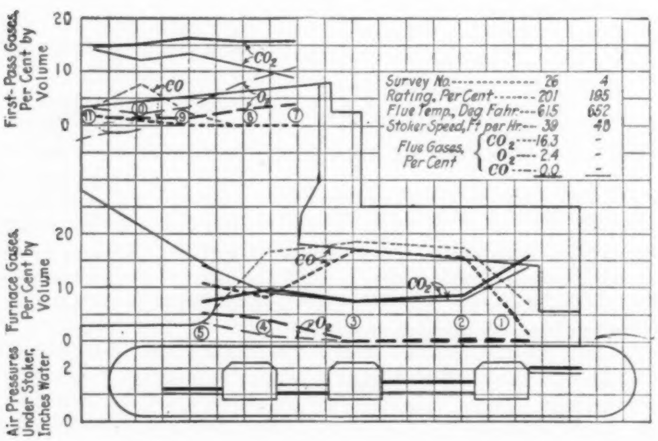


Fig. 11 Actual Effect of Rear Arch

but had been mixed thoroughly with the other gases in the furnace.

The opportunity which presented itself to install new baffles, in connection with other plant changes, had made possible the alteration of the furnaces. At present the line of the top of the reversing arch was extended until it met the tubes. It was impractical to raise the boilers in this plant to provide more vertical distance between the grates and tubes, although this change would probably be advantageous.

That these improvements in gas composition were actually translated into increased efficiency, had also been shown by the New York Steam Corporation (Fig. 12). Here the solid lines represented the variation in the heat balance with the rate of operating, as shown by five complete thermal-efficiency tests in February, 1924. The broken line represented the efficiency as it had been estimated to be at the various ratings with the single-arch furnace by a competent engineer familiar with the installation. The improvement was gratifying. The greater improvement with increased rate of driving was also evident, as was the fact that the maximum efficiency had been reached at from 170 to 180 per cent of normal rating. The engineers of the New York Steam Corporation had explained this by two facts. The reduction in gas loss by increase of CO_2 and elimination of CO was the first. The second was that the lower total gas quantity, at any given rate of combustion, lowered the gas velocity and consequently the weight of coal lost to the stack as fly cinder.

The solid line at the top of Fig. 12, however, representing the

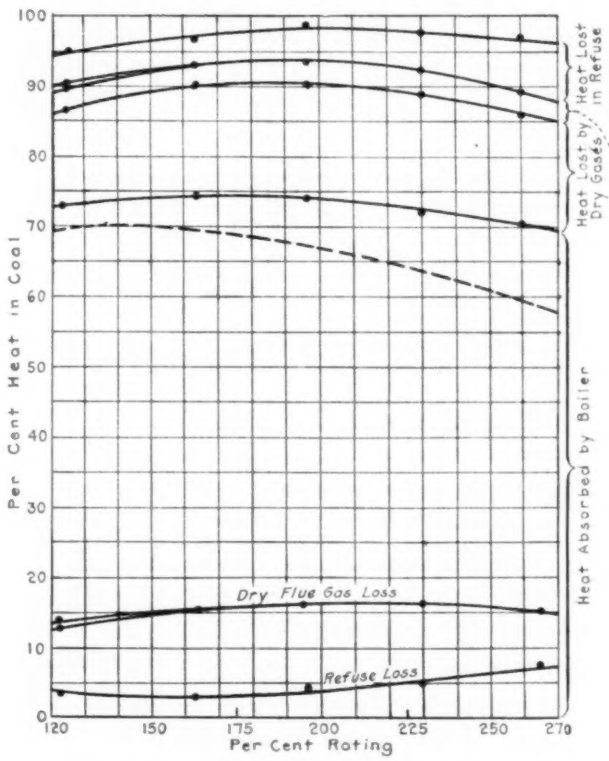


Fig. 12 Heat Account of Tests of Boiler No. 12 at Station A of the New York Steam Corporation

total percentage of heat accounted for, dropped away from the 100 per cent line after the rate of driving had passed about 200 per cent of rating, indicating that the quantity of cinders carried with the gases increased enough to offset improved combustion conditions. This indicated that excess air must be kept at a minimum in any given furnace or that a furnace must be designed for a definite maximum gas velocity below which the quantity of cinders would not cause a serious loss.

The only point of difference noted between the authors' statements and the experience of the New York Steam Corporation was that there were 12 boilers in the latter's Station A which had been in service for one year, equipped with reversing arches, and in that time no trouble had developed with any of the arches and, under what was considered hard service, no boiler had ever had to be shut down on account of cinders on the reversing arch, which was comparatively flat on top.

Howard H. Dalton[1] wrote that the information given by the authors did not clearly demonstrate the superiority of the final, or two-arch, over the three-arch design, as there had been no trouble with the arches; and the efficiency of the latter had been slightly higher. The only objection seemed to be the formation of slag on the rear arch. The two-arch furnace had the disadvantage of relying entirely on a restricted passage for the mixture of the rich and lean gases, and naturally, on low ratings, this mixture would not be as complete as at high ratings. If the passage was restricted sufficiently to get the best results on low ratings, high ratings would be impossible. For this reason the two-arch furnace, while it might meet the requirements of the Amsterdam plant, described in

[1] Engr., Construction Division, Am. Sugar Ref. Co., New York, N. Y. Mem. A.S.M.E.

the paper did not seem as good a design as the three-arch furnace.

Furthermore it did not seem that the removal of the top arch and the slight change in design of the rear arch would in themselves prevent slagging. The Baltimore furnaces of the American Sugar Refining Co. mentioned by the authors had three arches almost identical in design with the boilers under discussion. These had shown absolutely no slagging up to rates of driving of 270 per cent, which was the maximum possible with the draft available. The Baltimore plant burned a much finer coal than the Amsterdam, and this, if anything, should favor slagging at Baltimore.

The main operating difference (and it might be an important one) was that at Amsterdam the greatest pressure was carried in the wind boxes under the front end of the stoker, gradually reducing toward the rear end, while at Baltimore this condition was reversed. The Baltimore method of operation gave more excess air and lower temperatures under the rear arch and higher CO toward the front of the furnace, with the two gases mixing under the upper, or third, arch. That these gases did thoroughly mix, had been proved by CO_2 readings taken at five points across the boiler at the last pass. The average CO_2 at the damper had been over 14 per cent at rates of driving above 100 per cent, and over 15 per cent at rates above 140 per cent, with only a slight trace of CO. The efficiencies obtained had been about the same as those at Amsterdam up to 160 per cent of rating, but somewhat lower on higher rates, as was to be expected when burning the finer coal. The difference could be accounted for entirely in the cinders carried into the back connections by the high air pressure.

E. B. Powell[1] wrote that with reference to the design of the Baltimore furnace mentioned by the authors, his company was chiefly interested in determining the flexibility of a traveling-grate type of stoker in handling anthracite of very small size. The load conditions in the design of that plant had involved sudden and large changes in boiler demand. The company had been able to make some tests at one of the anthracite collieries on an installation which presented the basic principles of the two-arch furnace. While this installation had not much of a front arch, it still had all the fundamentals of a two-arch design. In this furnace it had been found possible to burn a very small size of anthracite, known as No. 4 buckwheat, at grate-travel rates changing almost instantly from about 20 ft. per hour to something like 50 ft. or more per hour, without affecting the ignition. That experience had indicated that there were great possibilities in the two-arch design, both from the standpoint of flexibility and from that of economy. The three-arch design finally decided upon, had been arrived at solely from considerations of economy. For the particular requirements in hand the third arch had seemed necessary to insure thorough mixing of the gases and proper utilization of the boiler heating surface.

His company had had another occasion to check the effectiveness of the third arch. They had found that where the gases leaving the passage between the lower two arches would have a compositon ranging from as high as two to six per cent CO and less than one-half of one per cent oxygen in the stream next to the front arch, to no CO and 12 to 14 per cent oxygen in the stream next to the rear arch, they had been able to obtain beyond the third arch a practically uniform gas mixture, 14 to 16 per cent CO_2 with a total absence of CO, and practically complete cessation of flame.

N. G. Reinicker[2] wrote that he heartily agreed with the methods outlined by the authors for improving the overall economy of equipment using small sizes of anthracite. At the Hauto plant of the Pennsylvania Power & Light Company, experiments along similar lines on various boilers and furnaces had led to similar results.

H. S. Colby[3] wrote that the experiences of the authors paralleled his own to such a marked degree that a brief outline of his work might be of interest.

In burning coke breeze in the conventional single- or front-arch furnace, practically the same difficulties had been encountered as were encountered by the authors in the burning of anthracite. The nature of these difficulties had suggested the use of an arch at the rear of the furnace. This arch had not been installed on a coke-breeze-burning stoker installation, however, until after his company's initial contact with the burning of anthracite coal.

In the fall of 1921 and spring of 1922 several Harrington stokers had been installed to burn fine-sized anthracite. These initial anthracite installations had been made, some with front arches only and others with front and rear arches. The arches had been of several lengths and set at various degrees of inclination. The operation of these stokers had made it apparent that the results obtained from furnaces with both front and rear arches were much more satisfactory than those with front arches only. The work of the last two years had been confined to establishing the proper proportioning of front and rear arches and throat (or space between the arches) for the various sizes of anthracite, and to determining the effect on arch design of height of setting or length of gas travel, and combustion rates.

The work to date had indicated that the rear arch afforded the means for obtaining the highest efficiency in the burning of all sizes of anthracite; that the throat area or space between the arches in which the gases were mixed should be modified with the fuel, rating, and setting height. Primarily, the area of the throat was a function of the maximum rating. Little or no improvement in quality of gases was obtained when the velocity of the gases passing through the throat exceeded 3000 ft. per min. The throat area could be increased as the setting height was increased, that was, as the length of gas travel from the throat to the tubes was increased. The rear arch should be set at a slight angle to the horizontal and so located with reference to the front arch that gas comparatively rich in oxygen generated on the section of grate under the rear arch, would travel across the throat and mix with the gas lean in oxygen passing out from under the front arch.

While the front- and rear-arch design had been developed primarily for the more efficient burning of anthracite and coke breeze, the same general design of furnace was also more efficient for the burning of bituminous coal than furnaces with a front arch only.

The authors, in their closure, wrote that there was room for considerable difference of opinion regarding the relative merits of two-arch and three-arch furnaces. In the case of the particular problem at Amsterdam, the two-arch furnace appeared to be necessary. The boiler and the stoker had been both set, and changing the location of the stoker meant changing the ash hopper and some of the building steel, which would have been very expensive. A better furnace of the three-arch type might have been obtained if the boiler could have been changed or the stoker shifted, but the expense of such changes could not be justified. The problem they had had was that of adapting a furnace to a boiler and stoker which were already installed. The two-arch furnace had appeared to be the solution for this particular problem. It might not be the solution for another set of conditions. They were not sure that the two-arch furnace was quite as good for a wide variety of loads. It was possible that under very low rates of operation, with a low velocity of gas passing through this furnace, there might be a tendency toward stratification. The boilers described in the paperwere taken off the line if the load dropped below 170 per cent of rating. Below this rating it might be possible to get that action; above it, they did not. Hence in that particular case the furnace was satisfactory. For another installation it might not be. The furnace described was not a panacea, but only a step in the solution of the problem.

Both Mr. Mumford and Mr. Dalton had expressed surprise that there should be any difficulty due to the deposit of cinder on the rear arch. The authors did not know the cause of their troubles. On the first experimental arch, the short arch that had not been described, cinder did accumulate, but it accumulated in a comparatively cold state, and rolled off the arch as soon as the angle became sufficiently steep. They knew that this happened at Baltimore and believed that was what Mr. Mumford had experienced. One might suppose that a difference in the fusion temperature of the ash was responsible, but the coal used in the first experiment had been substantially the same coal as used later, and probably there had not been much over 100 deg. fahr. difference in the ash-fusion temperatures of the two coals. The coal had come from exactly the same districts and had had practically the same specifications.

[1] Cons. Engr., Stone and Webster, Inc., Boston, Mass. Mem. A.S.M.E.

[2] Supt. of Operation, Pennsylvania Power & Light Co., Allentown, Pa. Assoc-Mem. A.S.M.E.

[3] Asst. to Sales Mgr., Riley Stoker Corp., Worcester, Mass.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

De Havilland "Baby Plane"

PARTICULARS of a two-seater weighing only 770 lb. and capable of 90 m.p.h. with a fuel consumption of 20 miles to the gallon. The plane is called the "Moth" and is equipped with a 60-hp. Cirrus engine. It is designed for use by flying clubs and schools and it is said that in the air it is steady and easy to fly, and has a stalling speed with full load at 40 m.p.h.

The Cirrus engine, for the sake of cheapness, was produced from parts employed in the 120-hp. Airdisco engines (originally the French Renaults of war-training-ship fame). The new engine is virtually a complete half of the 120-hp. Airdisco and is air-cooled. One of the interesting features of this plane is the ease and speed with which the wings can be folded. With the wings folded the machine has a total overall width of 9 ft. 8 in., which makes it possible to store it in a garage and to tow it along roads behind an automobile. The operations of folding or spreading the wings can be performed by one man in less than three minutes, and when they are swung into position for flight no truing up or adjustment is necessary.

The starting arrangement is of the ratchet type and similar in principle to the kick starter of a motorcycle, only it is operated by the hand lever. The engine weighs 260 lb. dry, equivalent to 4.33 lb. per hp. (*Automotive Industries*, vol. 52, no. 19, May 7, 1925, pp. 830–831, 3 figs., *d*)

The Boulton-Paul "Bugle" Day Bomber

DESCRIPTION of a new metal-framed, twin-engined, medium-range biplane fitted with a Bristol-Jupiter engine. It has wings of equal span but of greater chord at the top than at the bottom. The most striking features concerning the control surfaces are the huge size of the rudder and the method of balancing.

The balance used is essentially of the horn type, but, instead of overhanging the wing or fin, the horn pieces have their leading edges inset into the surface ahead of them, so that they are shielded thereby at smaller angular settings from normal, while the leading edge of the horn is in way of the surface ahead of it. With the usual horn type of balance, the aileron or rudder tends to be unstable at small angular settings unless the balanced area is reduced to such an extent that at large settings the surface is markedly underbalanced. With the shielded horn at fine angles, the fixed and moveable surfaces together act as one combined surface, and the instability disappears. When the angle is sufficient to bring the leading edge of the horn clear of the forward surface, the region of instability has passed.

By avoiding this instability of the horn balance this type of balancing allows greatly increased balancing to be used at the large angles. As a result, on the "Bugle," the pilot is able to hold the rudder in any position at any speed. He can turn against one engine even without using the compensating springs. Incidentally this rudder is sufficiently powerful to overcome the aileron yawing moments when the machine is stalled, and this machine, having ample longitudinal control and stabilizing surfaces, is therefore of the class which can be controlled beyond the stall.

The engine mounting is of the hinged type and the hinge pins are very long, hardened and ground to standard Morse taper, and then fitted into hardened hinges and screwed up fairly tight into position. To prevent their being screwed up too tight, the nut on the hinge pin is made circular and provided with holes for a tommy bar. A tommy to fit each of these nuts of very limited diameter and of soft material is secured to the engine mounting by a steel chain and incidentally is used to lock the nuts in position. Any attempt to overtighten merely bends the bar. (*The Aeroplane*, vol. 23, no. 17, April 29, 1925, pp. 412–416, 5 figs., *d*)

AIR MACHINERY

The Aerodynamo Wind Mill

TESTS carried out at Harpenden by the Institute of Agricultural Engineering of Oxford University to prove the efficiency of a new type of windmill device for generating electricity, suggest that the difficulties encountered with previous wind-power machines have been overcome. In appearance, the aerodynamo has four blades mounted on a 30-ft. concrete mast. The generator, which is to leeward of the dynamo—an important innovation—is connected directly with the blades by means of gearwheels. The two principal features of the aerodynamo are the shape of the blades and the air brakes. The blades are constructed according to the latest results of airplane experience and aerodynamic researches. The air brakes, which work on the principle of centrifugal force, automatically place a limit to the maximum speed of rotation, even in the highest winds.

In tests the aerodynamo is stated to have generated power in a breeze scarcely perceptible to the onlookers and to have developed 10 kw. in all wind velocities above 18 m.p.h. This output is not exceeded owing to the braking system, and it is claimed that a really steady power flow is maintained. (*Machinery* (London), vol. 26, no. 656, Apr. 23, 1925, p. 101, *d*)

ENGINEERING MATERIALS

Fire-Resistant Iron Castings

A PROCESS has recently been developed in which castings can be poured in molds containing a network of aluminum wires. The aluminum is absorbed and a hard-alloy layer forms on the surface of the casting which gives as good a protection against high temperatures as in the case of aluminum externally applied. (*Machinery* (London), vol. 26, no. 655, Apr. 16, 1925, p. 73, *d*)

Thermonit Mortar and Firebrick Dope

THERMONIT is a material which can be used either as a mortar or fireproof cement, or applied in a very thin layer (0.2 to 0.4 in.) According to a statement of the manufacturers, The Vinco Company, of Berlin, it provides a high degree of heat protection. No data as to its composition are given. (Technical Exposition in Leipzig, Foundry Section, described in *Zeitschrift fur die Gesamte Geissereipraxis*, vol. 46, no. 16, Apr. 19, 1925, pp. 201–202, *d*)

Strength of Steel Cut by Torch

FOLLOWING the report that the highway commission of a western state had frowned upon the cutting of structural steel for highway bridges by the oxyacetylene flame, the Union Carbide & Carbon Research Laboratories, Long Island City, N. Y., undertook an investigation of steel surfaces severed by the oxyacetylene flame, by shearing, by hacksaw, and by friction saw.

Square bars were cut from $^3/_8$-in. mild-steel plate by several methods and each bar was tested as a beam in bending. One of the bars was cut by a hacksaw, the second with the oxyacetylene flame, the third cut oversize by the oxyacetylene flame and the surface cut milled $^1/_8$ in., and the fourth specimen was sheared. Another series of tests were made on bars cut from the web of an I-beam, and parallel experiments were made on angle bars cut by a friction saw. From these experiments it would appear that the hardened and carbonized surface produced by the oxyacetylene flame is seldom more than $^1/_8$ in. deep and can be removed by the $^1/_8$-in. cut. Bars that were sheared bent easily and cracked; bars cut by the friction saw also showed low strength, and numerous small cracks developed under small deflections. The experiments also showed that a surface cut by the oxyacetylene flame is some-

what harder and stiffer than the original model and has good ductility. (E. E. Thum in *Iron Trade Review*, vol. 76, no. 20, May 14, 1925, p. 1262, 1 fig., *e*)

Balsam-Wool Insulation Tests

Balsam-wool is made from the fibers of coniferous northern woods chemically treated so as to make them fireproof and decay-proof. In this condition the fibers, which are fine, hairlike, hollow tubes, are next bound together with cement, with the axes of the fibers, however, extending in all directions and not parallel to each other as in wood. The result is a resilient blanket of fibers which weighs only 5 lb. per cu. ft., or less than one-half the weight of cork. It contains countless still-air cells, and it is said that over 94 per cent of the volume is still air. To increase the mechanical strength of the fibrous blanket it is covered on both sides with a layer of creped waterproof Kraft paper which is cemented to the blanket of fibers by a high-melting-point asphalt. This material is called "Balsam-Wool" and is made by the Wood Conversion Co., Cloquet, Minn.

Tests on it were conducted by Howard F. Weiss, research engineer of the C. F. Burgess Laboratories, Madison, Wis. The test showed that Balsam-wool will absorb about 30 per cent moisture, or over twice as much as cork when subjected for a long time to a humidity of 90 per cent or more. However, at 30 per cent moisture Balsam-wool is said to contain less moisture per square foot than cork at 5 or 10 per cent moisture, because of the former's extremely low density. Therefore its thermal resistance, even when subjected to high and to prolonged humidity, is not seriously impaired.

In tests for thermal conductivity the average heat flow in 24 hr. through Balsam-wool was found to be 6.1 B.t.u. per sq. ft. per in. thickness per deg. fahr. It is not stated where the thermal-conductivity tests were made. (*Railway Age*, vol. 78, no. 21, Apr. 25, 1925, pp. 1041, 1042, 2 figs., *d*)

FOUNDRY (See also Materials Handling: Handling Materials in the Foundry)

Centrifugal-Casting Calculations

The author discusses in particular the production of centrifugal castings on a vertical or inclined axis and presents equations which show how the paraboloidal bore of the casting may be elongated to the desired extent, what speeds are required to make a given casting, and the quantity of metal which has to be introduced to make the casting.

Equations derived by the author are a development of those given by Lilienberg in *Blast Furnace and Steel Plant*, July, 1922, and the author's paper, Control of Centrifugal Casting by Calculation, in Mechanical Engineering, November, 1921. (Robt. F. Wood, Metallurgical Engineer, Newark, N. J., in *The Metal Industry* (New York), vol. 23, no. 5, May, 1925, pp. 186–189, 5 figs., *tp*)

Centrifugal Casting of Large-Diameter Cast-Iron Pipes

Description of a process operated by Centrifugal Casting, Ltd., at Kilmarnock, England, by which pipes have been produced with diameters up to 36 in.

The most interesting future of the new arrangement is the pourer (in America the pourer is also known as the "spout") by which metal is supplied from the ladle to the mold. The important problem in centrifugal casting of this character is to deposit the metal evenly over the whole surface of the rotating mold. It was first attempted to do this by a pourer equipped with a horizontal weir edge of approximately the length of the casting to be produced, and arranged to be tilted by partially rotating about its axis in such a manner that the metal was deposited on the surface of the rotating die in a continuous sheet of a length approximately equivalent to that of the casting being produced. This pourer was first modified by forming the weir edge in a series of steps varying in height along the length of the trough. This gradually led to giving the weir edge such a shape as to form a portion of a helix. The partial rotation or tilting of this trough through the complete angle subtended at the axis of the pourer by the difference in level between the two ends of the weir edge is said to result in the continuous deposition of the molten metal in a complete series of annular rings of narrow width, depending upon the velocity of the molten metal supplied. This system is referred to as the Hurst-Ball system. The castings as produced do not need annealing. (*The Engineer*, vol. 139, no. 3615, Apr. 10, 1925, pp. 416, 4 figs., *d*)

Making Castings in Permanent Molds

Description of a process developed essentially by two men, Hubert A. Myers and H. S. Lee, the purpose of which is to make such castings as pistons, sash weights, etc. The molds in which the castings are made have to be quite hot, and in practice it was found that the metal of the castings had a tendency to stick to the metal of the molds.

After a good deal of trouble this was obviated by impregnating the iron of the mold with zinc. When the molten metal strikes the surface of the mold this causes an extremely small amount of the zinc to gasify and sets a thin film of gas between the metal and the mold. Careful design of the mold is required to overcome the tendency of this gas to be distributed unequally over the surface of the mold. It is claimed that the castings made by this process are soft and machinable. By changing the thickness of the mold, chills may be produced when desired. This feature is illustrated in plow points which are made by this process. (*Iron Trade Review*, vol. 76, no. 21, May 21, 1925, pp. 1325–1328, *d*)

FUELS AND FIRING (See also Engineering Materials: Thermonit Mortar and Firebrick Dope: Special Processes: Open Hearth with Furnace Pressure Control)

The Trumble Oil-Shale Cycle-Distillation Plant

Description of the experimental plant of M. J. Trumble at Alhambra, Cal. Mr. Trumble is the inventor of the Trumble refining process, the Trumble gas trap, and other devices extensively used in the oil industry. The process is cyclic in character, i.e., instead of distilling oil from the shale in one operation and then distilling the crude oil into gasoline and other products in a second operation, the gasoline is produced from the oil shale through one continuous operation in which the crude oil occupies only an intermediary stage.

The shale broken to fairly small sizes is first delivered to a preheater and subjected to a temperature of 400 deg. cent. From there it passes to a retort. Vapors from the cracking still (which is a later element in the process) enter the lower part of the retort, come in contact with the raw shale preheated to 400 deg., lose a part of their own heat, and raise the temperature of the shale. Superheated steam is injected at this stage.

The entire product from the retort goes to the dephlegmator where a separation and condensation is made of the light and the heavy oil. Light cut, or gasoline distillate, passes to an agitator where the pyridine and other impurities are removed as an acid sludge, which is later redistilled to recover the pyridine and the acid. The light-cut gasoline is redistilled in the presence of saturated steam and condensed into water-white gasoline. The heavy cut is returned to the cracking still where it is recracked and follows the cycle.

The cracking stills are of essentially conventional design, except that a revolving spiral device removes the accumulating carbon around the tube from which it is carried to a carbon pot. Steam and oil vapors from the retort pass to a steam turbine connected to a generator to produce electricity for general power uses.

Tests on the crude shale oil and gasoline made by Prof. R. A. Baxter at the Colorado School of Mines (complete figures in the original article) show a promising production as far as the character of the product is concerned. No data as to the percentage of recovery are given. (*Combustion*, vol. 12, no. 5, May, 1925, pp. 354–355, 1 fig., *d*)

HYDRAULIC ENGINEERING

The Homeyard Hydraulic Valve

Description of a high-pressure hydraulic valve guaranteed to operate at 3500 lb. per sq. in. pressure without leakage, and manu-

factured by Glenfield and Kennedy, Ltd., Kilmarnock, Scotland. It consists of a gun-metal body A which is bored out to receive two gun-metal spindles, B, B, one of which acts as a pressure valve and the other as an exhaust valve. These two spindles are coupled together at the top by means of a connecting lever C and crossheads D, D on the top of the spindles. At a point midway between the two spindles on the lever a pin E and two side links F, F are fitted these latter passing down the sides of the valve body to the under portion, and being connected together at their bottom ends by a gun-metal crosshead G. On this crosshead there bears a small ram H the cylinder of which is bored out of the valve body, looking downward; the hydraulic supply for this ram is taken from the inlet branch of the valve through a small hole drilled at I.

The constant downward thrust is thus exerted on the small ram

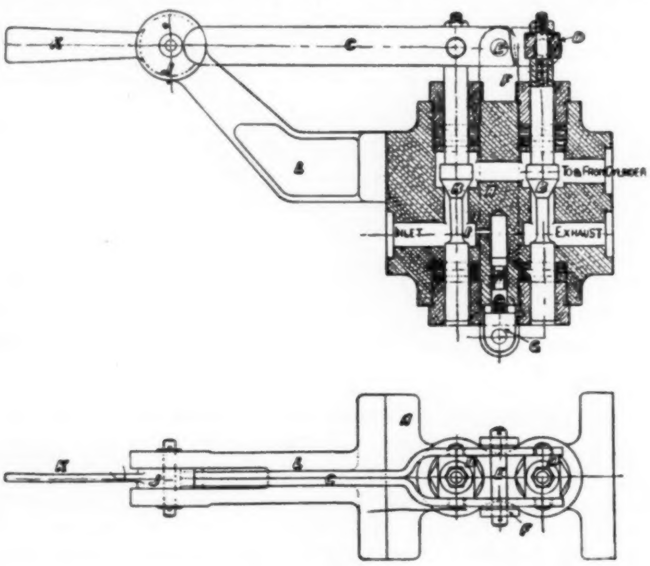


FIG. 1 HOMEYARD HIGH-PRESSURE HYDRAULIC VALVE

H, which thrust is transferred through the side links F, F and lever C to the valve spindles B, B. As the valve spindles themselves have pistons of exactly the same size at top and bottom and are therefore in equilibrium, the constant thrust from the small ram H tends to keep the valve closed. The valve lever C is rounded at its outer end and bears in a recess formed in the cam plate J on the handle K, the rubbing surface on both the valve lever and handle being case-hardened to avoid wear.

When the handle is moved upward or downward it moves the engaging end of the valve lever in the opposite direction, and thereby raises one or other of the valve spindles, the one at rest on its seating forming the fulcrum for the time being.

If, now, the handle be raised or lowered sufficiently, it throws the end of the valve lever entirely out of the recess in the cam plate, so that it bears on the circumference of the cam plate, and thus locks the valve in the open position. Directly, however, the operator moves the hands back sufficiently to allow the valve lever to re-enter the recess in the cam plate, and removes his hand from the handle, the small ram on the underside of the valve body brings both lever and handle to the mid-position, thereby closing both spindles down on their respective seats.

It is stated that in the smaller sizes the finger and thumb alone are sufficient to control pressures up to 1000 lb. per sq. in. In the double-ported-valve type one handle only is required for the two cylinders. (*Mechanical World*, vol. 77, no. 1999, Apr. 24, 1925, p. 268, 1 fig., *d*)

Reduction of Velocity in Measurements of Water Flow

ONE of the methods of measuring water is to take readings at a few points located a little under the surface of the water. In order to derive the average velocity of flow u from the sub-surface velocity readings u_0 or in order to derive the flow directly from the formula $Q = uF$, wherein F is the cross-sectional area of the flow, a number of formulas have been proposed, some of which are discussed in detail by the author. He then proposes a method of his own which he claims is more precise than those now used. This method is based on the following considerations. If it is intended to construct a complete curve of flow (i.e., one suitable for high water also) for a flow profile, it is necessary to select a profile as uniform as possible and located in a straight section of the flow. If this is done it is permissible to consider in the first approximation the various water levels of the given cross-section as similar. Let then the average profile velocity at the level h be u and at h' be u'. In accordance with the dimensional theory, $u = [lt^{-1}]$ and $u' = [l't'^{-1}]$. If we write $l' = \lambda l$ and $t' = \tau t$, then

$$u' = \frac{\lambda}{\tau} u \qquad [11]$$

This equation holds good also for the corresponding average velocities at the cross-section, or

$$u'_0 = \frac{\lambda}{\tau} u_0 \qquad [12]$$

where the average velocities of the cross-section have to be calculated in accordance with

$$u_0 = \frac{\Sigma (f u_0)}{F} \qquad [13]$$

(f being an element of the area of the cross-section). From Equations [11] and [12] it follows that

$$u' = \frac{u}{u_0} u'_0 \qquad [13a]$$

Putting $u/u_0 = k$, and in order to take care of the imperfect similarity of the various cross-sections through which the flow takes place, making the exponent of u'_0 not 1 but v, which has a value only a little different from unity, then

$$u = k u_0^v \qquad [15]$$

For practical purposes, however, it is more convenient to give Equation [15] the logarithmic form of

$$\log u = v \log u_0 + x \qquad [16]$$

The constants v and x may be computed by means of measurement over the same cross-section at a large number of points wherever this is possible, and the computation may be carried out by the method of least squares, though the author recommends preferably the use of the correlation method as giving a better insight into the mutual relations of the various factors.

The author gives an example in the form of tables of eight measurements carried out with a precision of 1.2 per cent, and claims that where the measurements have been made very carefully the average error is still lower. He points out, however, that it is not desirable to apply Equation [16] to any case where, in the computation of v and x, the correlation factor r is less than 0.95, because in such a case the profile is either very irregular or quite variable. (Wilhelm Reitz, Chief of the Hydrographic Bureau for Steiermark in Graz, in *Schweizerische Bauzeitung*, vol. 85, no. 19, May 9, 1925, pp. 239–240, *t*)

INTERNAL-COMBUSTION ENGINEERING (See Testing and Measurements: Codes for Recording Heavy-Oil-Engine Trials)

MACHINE PARTS AND DESIGN (See Metallurgy: Gears)

Convention of American Gear Manufacturers' Association

THE convention took place in Pittsburgh, May 6–9. In a paper on the Development of the Gear Art, Frank Burgess, president of the Boston Gear Works, Quincy, Mass., stated that the gain in the direction of the harder material was at the expense of quietness. One had the choice of an untreated gear of short life on the one hand, or a hardened but noisy gear on the other, there being more or less distortion in the best heat treatments.

Refinement of inspection instruments and of gear-cutting machinery were pointed to as the latest developments in the gear "art." Various recently developed testing instruments were enumerated and the improved testing equipment available was said to practically permit of visualizing the "noise" in a pair of gears and definitely place the fault at the machine or the cuter. It was thought that there is a field for some American tool manufacturer in the development of a simple noise-testing instrument with a recording device, so that noise can be standardized. The final test of a gear, it was said, is the noise test, and regardless of the instruments used to check the accuracy of the gear in its manufacture, if the gear is noisy it is rejected.

The ground-tooth gear was stressed as an important development of recent years. In a laboratory test made by Mr. Burgess' company, an 8-pitch, 16-tooth hardened steel pinion with hardened teeth was arranged to run with an 8-in.-pitch-diameter cast-iron spur gear. Both gears were of $1^1/_4$-in. face and operated at a peripheral speed of 600 ft. per min. This combination is said to have developed 40 hp., although according to the Lewis formula the rating of a soft-steel pinion running with a cast-iron gear of this size would not be more than about 5 hp. The large amount of power transmitted by this combination was said to be due to the fact that the hard, smooth surface of the ground-tooth pinion engaging the cast-iron gear served to glaze over the teeth of the cast-iron gear, giving it at the same time a hard and smooth or burnished surface.

In discussing Future Possibilities in Gear-Manufacturing Equipment, F. W. England, vice-president of the Illinois Tool Works, Chicago, stated that it was not beyond possibility that alloys might be developed that would permit of casting gears in molds and obtain equal strength to those now made by forging and cutting. These cast gears probably would be finished by grinding only, using helicoidal grinding wheels of unusually large diameters and grinding several gears simultaneously.

The possibilities of the swaging process applied to steel had not yet been exhausted. Eventually we might have completed gears formed by enormous pressure exerted for a sufficient time for the alloy material to flow into accurate molds.

Spur and spiral gears, sprockets, spline shafts, and a variety of special gears are made by hobbing, which, it was said, has surpassed its brother methods in rapid production of high-grade work. It was predicted that automatic generating machines equipped with hobs made of steel of increased strength and hardness, "will soon appear at the horizon of thought to find some one to pilot them safely to shore." Present hobs are cylindrical cutters of comparatively quick peripheral curvature, and they will, therefore, not form straight gear teeth without traversing the face of the gear. Hobs of larger diameter have slower curvature and can be fed faster without affecting the finish, but economical construction of a hob of sufficient diameter to cut a gear within practical limits, without the traverse feeding, is beyond comprehension. A suggestion for a hobber, it was stated, may be derived from the caterpillar tractor. Such a machine would have an endless chain for a cutter, a chain provided with hob teeth, against which the work would be fed radially.

Both speakers emphasized the importance of the generating process of forming gear teeth, F. W. England thinking in terms of machines with magazine loaders, continuous moving generators, gear blanks automatically fed to the generators, and finished gears departing from them by conveyor to be placed in the automatic loaders of other machines to perform the next operation.

The other papers dealt with the influence of gear development in the automobile industry, the gear industry on the Pacific coast, limiting values in spur gears, and the application to gear design of photoelasticity. (*The Iron Age*, vol. 115, no. 20, May 14, 1925, pp. 1435–1437, *g*)

MACHINE TOOLS

A.C. Reversing Motor-Drive Arrangement for Planers

Description of a drive (referred to as "super drive") for planers intended to permit of all the advantages of a direct-connected reversing motor drive in plants in which only alternating current is available. The advantage of the direct-current adjustable-speed motor connected directly to the planer is due to the higher cutting and return speeds, the ease of obtaining any cutting speed, the accuracy of reversal, and the lower maintenance cost of the reversing motor drive.

In the "super drive" equipment a direct-current adjustable-speed reversing motor is connected directly to the planer. Current for this motor is furnished by a generator driven by a motor which uses the a.c. current from the main line. The connections between the planer motor and the generator are never broken when in use, and therefore a controller with a multiplicity of relays and contactors for carrying the large armature current is not required. The entire control of the motor for direction and speed is obtained by manipulation of the small field current of the generator. Reversal of the field current of the generator changes the direction of the generated current and reverses the rotation of the planer motor. Reversal of the generator field is by means of an oscillating drum switch operated by dogs on the table, the contacts being closed and opened under oil in the inclosing case.

Changes in speed of the planer motor are obtained by varying the field current of the generator. Reducing and increasing the field current lowers and increases the voltage of the generated current, respectively, and lowers and increases the speed of the planer motor. The changes in the field current are obtained through separate rheostats adjusted by hand for the cutting and return strokes; therefore any cutting speed may be used with any return speed within the range of the equipment. Cutting speeds up to 60 ft. per min. and return speeds as high as 160 ft. per min. can be obtained.

A feature emphasized is the safety pendant switch, which is suspended from a swivel on the arch or cross-tie of the planer by a flexible cable, thus placing it close at the operator's hand when working. The entire control of the table motion, starting, stopping, reversing, or jogging by small fractions of an inch, is obtained by the single knob on this switch. The machine when running may be stopped instantly by pushing the knob upward. (*The Iron Age*, vol. 115, no. 18, Apr. 30, 1925, p. 1274, *d*)

Compound Car-Wheel Lathe and Grinding Machine

Description of a heavy-duty machine made by Hulse & Co., Ltd., Salford, Manchester, intended for use in machining worn car wheels.

The conditions of locomotive and railway car wheels when brought in for re-turning are essentially different, as deep cuts are often necessary on locomotive wheels. In car wheels there is in general little flange deformation, but in many cases flats form on the circumference of the tread and hard spots are present as the result of skidding. These cannot be turned through and the common practice is to take a cut deep enough to get well under them. This is, however, a wasteful method, as more than the necessary amount of metal is taken off.

The grinding wheel lathe described here has been introduced mainly to obviate this wastage. It consists essentially of two headstocks each with suitable drivers for driving the wheels, two tool rests and two self-contained grinding heads. Each tool rest is fitted with a gaging device and four tools—one for the tread, one for topping the flange, a forming tool for the flange, and a tool for the chamber. These tools are set to determined positions by a gage.

By means of the gaging device the operator can find the lowest point of wear on each wheel, i.e., the maximum diameter up to which it is possible to clean both wheels. A cut is started on the treads and on the flange simultaneously, and due to the indexed rule on the tool slide and the tool being set to the gage, it is insured that both wheels are similar in diameter. The tread on the outside is slightly humped up for about 1 in., partly owing to rolling of the metal, and it is possible to turn this before encountering the hard places, and when they are reached the turning is stopped. It is possible, of course, to omit this turning, but generally it is the more economical method.

The remainder of the tread is ground, and it is possible, due to this method, to just clean up the wheels, leaving the semblance of the previous outline. After the grinding is completed on the tread, the flange is finished with the former tool. (*The Railway Gazette*, vol. 42, no. 20, May 15, 1925, pp. 672–673, 2 figs., *d*)

MARINE ENGINEERING

Results Obtained with the Rotor Ship

THE original article contains a table giving actual figures, in particular, of wind direction and speed, indicated and effective horsepower, tower-motors horsepower, total horsepower, speed in knots, the *U/V* factor, which is the ratio of speed at circumference to speed of wind, etc. For generating the necessary power to turn the rotors at a rate of 110 r.p.m. a 45-hp. Diesel-driven dynamo is used. It appears from the figures given in the original article that under the most favorable circumstances the thrust developed by the rotors is equivalent to that given by about 110 to 120 hp. It would appear that a certain limit for the dimensions of the rotors is set, and this leads to a recommendation not to design rotors of larger dimensions than necessary to give about 50 per cent of the total thrust required for attaining a certain speed of the vessel. The conclusion arrived at is that about 20 per cent of the average horsepower of a propeller-driven vessel of, say, 11 knots may be taken over by rotors. The development which is foreseen is in the direction of having a propeller-driven vessel assisted by rotors, with only about 20 per cent of the power developed by the latter. (Article based on communication from Dr. Ernst Foerster, German Naval Architect, in *Marine Engineering and Shipping Age*, vol. 30, no. 5, May, 1925, pp. 275–279, 5 figs., *dg*)

MATERIALS HANDLING

Materials Handling in the Foundry

ANALYZING the conditions prevailing in a foundry producing 100 tons of good castings daily, the author finds that 168 tons of materials have to be handled for every ton of goods produced. This includes the handling of equipment, patterns, sand, and the completed mold. He comes to the conclusion that there is probably no industry of heavy production which quite compares with the foundry business in the tonnage of materials handled to that of the tonnage produced.

In the handling of raw materials by manual labor the ordinary laborer will handle from 10,000 lb. to 100,000 lb. of material per day, depending upon the character and distance that the material is handled. In well-equipped foundries this averages about 40 tons per day per man of all the men employed, including the molders and other skilled men. It is obvious that the skilled men spend most of their time doing common labor and handling materials. The necessity, as well as the possibility, of handling materials in foundries with the proper facilities is apparent. The foundry, when viewed from the standpoint of material handling, offers a fruitful field for real progress. (Max Sklovsky, Chief Engr., Deere & Co. in *Open Shop Review*, reprinted in *American Metal Market*, vol. 32, no. 94, May 16, 1925, pp. 7, 9, 11 and 37, *p*)

METALLURGY

Some Metallurgical Considerations of Gears

THE ARTICLE here abstracted contains among other things a chart giving the chief characteristics of gear steels. It comprises chemical composition, mechanical properties, and heat treatment necessary for gears made of various types of steel, both plain carbon and alloy.

The subject of production of blanks from which gears are made is discussed extensively. The author points out that there is a correct and a totally wrong way of making blanks. (Figs. 2 and 3.) The direction of the grain of steel in gears is of paramount importance, and the author shows that there is a vast difference between gears made in the correct way and those made in the wrong way, whether made from rolled bars or forgings. The fact that the resistance to impact stresses, as measured by the Izod impact test, when such stresses are transverse to the direction of the grain of the steel, is more than twice that when the stresses are along the grain, is proof that this point is one to be noticed in particular. It is probably a common experience to most engineers to know of instances where gears have given satisfactory service for a time but have ultimately broken down in some of the teeth, and it may often be noticed that such teeth as prove defective are opposite to each other, while others are quite sound, although it is obvious that all the teeth have been subjected to precisely the same work and strain. The reason for this is often proved to be that the gear has been made from bar steel with the grain running across the gear as shown in Fig. 4, instead of the correct way as shown in Fig. 5. Apart from other considerations, this example should be sufficient to prove clearly the great desirability of always making important gears in the correct way. The correct way is also the most expensive, but the slight increase in manufacturing costs is more than made up by the superiority of the finished gear.

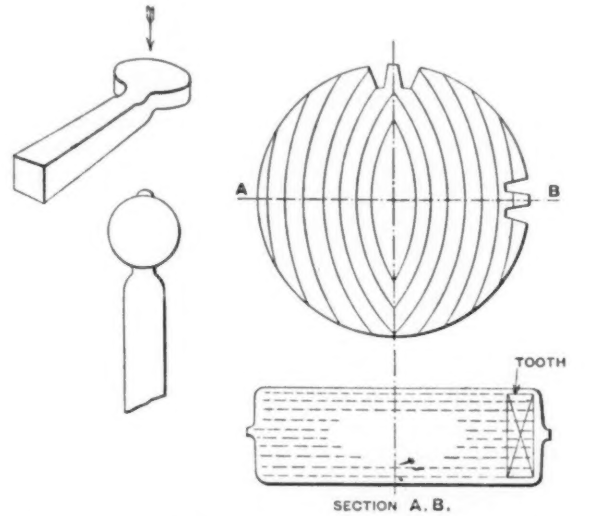


FIG. 2 DIAGRAMMATIC REPRESENTATION OF GEAR MADE BY THE WRONG METHOD OF STAMPING DIRECT FROM THE STEEL BAR

(In approximately half the gear teeth the lines of flow of the steel cut across the roots of the teeth, making them brittle and liable to break off.)

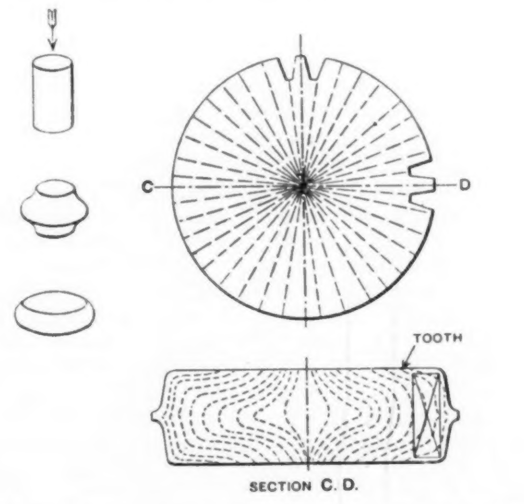


FIG. 3 DIAGRAMMATIC REPRESENTATION OF GEAR MADE BY THE CORRECT METHOD OF "UP-ENDING" THE STEEL

(The lines of flow of the steel run along each tooth, which makes them all equally strong and resistant to impact. Compare with Fig. 2.)

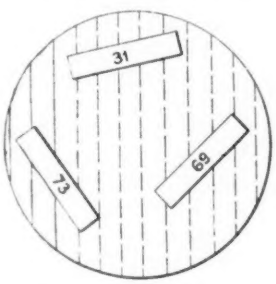
As regards the selection between carbon steels and alloy steels, it is claimed in the first place that it is dangerous to harden carbon steels too much, as they are apt to become more brittle than are alloy steels at the same hardness. It is true that many manufacturers still pin their faith to carbon-steel gears which have been hardened to about 100 tons tensile, but this practice is not good and is liable to result in trouble. At about 50 tons tensile such steels as these give quite good service for ordinary work, but after this their use is very limited.

The most important feature about alloy steels is that they are capable of being hardened to a high hardness figure and still retain a comparatively large percentage of ductility or toughness, which fact does not apply to carbon steels. Moreover, they are exceedingly strong, and having a high yield-to-break ratio are less liable to take a permanent set when severely stressed. Again, they mostly

are capable of being heat-treated in such a way as will make them highly resistant to impact stresses, which is one of the greatest factors in their favor for use as gears.

There are, however, certain disadvantageous features in alloy gears. In the first place, alloy steels require very careful manipulation throughout their entire manufacture, are mostly expensive to purchase, and are not easily machinable as compared with other steels. Furthermore, unless they are properly heat-treated they are not to be relied upon, and are, in fact, somewhat dangerous, because faulty heat treatment which has been applied without adequate knowledge of their peculiarities is prone to produce a structural condition which will scarcely compare with those obtainable from ordinary carbon steels.

In one respect alloy steels are, in the main, liable to suffer from a peculiar and highly important malady, which is that called



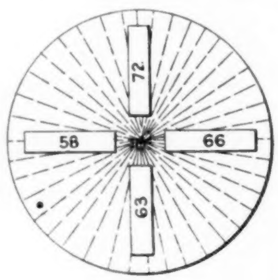


FIG. 4 (ENDWISE) IMPACT FIGURES (FT-LB.) OF GEAR MADE BY WRONG METHOD, AS ILLUSTRATED IN FIG. 2

FIG. 5 (LENGTHWISE) IMPACT FIGURES (FT-LB.) OF GEAR MADE BY CORRECT METHOD, AS ILLUSTRATED IN FIG. 3

"temper brittleness." The manner in which temper brittleness manifests itself is that it is possible to heat-treat an alloy steel to give a perfectly good combination of all the usual mechanical properties with the exception of its resistance to impact stresses, and it is this lack of impact value which is called temper brittleness. It follows, therefore, that a gear can be made which will be excellent in every way except in that characteristic, which is perhaps the most important of all, because if a gear is lacking in resistance to impact then its teeth are liable to break off. It is known, however, that the cause of this is slow cooling after tempering, and so it is absolutely imperative to insure that all gears are quickly cooled after they have been heated to their tempering temperature, which can be done by simply quenching in oil or water.

The case of special alloy steels, including case-hardening steels, for gears is also discussed. (MET. in *Machinery* (London), vol. 26, no. 655, Apr. 16, 1925, pp. 77–81, 6 figs., *pA*)

MOTOR-CAR ENGINEERING

New Rolls-Royce Overhead-Valve Engine

THE new engine is $4^1/_2$ in. bore by $5^1/_2$ in. stroke, six-cylinder, and is rated at 43.3 hp. under the formula of the Royal Automobile Club. Actually, however, it will develop in excess of 50 hp. at 2250 r.p.m. and it is stated that it can be run at well over 3000 r.p.m. without valve trouble.

The engine is fitted with a friction-driven flywheel damper at the front end completely enclosed in the half-time wheel casing with all the driving gears. The latter are of the helical spur-wheel type and are driven by a Rolls-Royce special friction-damped spring drive from the crankshaft. As many parts as possible are enclosed. Thus the camshaft, rollers, tappets, and driving gear are completely enclosed within the base chamber, and all other parts of the valve mechanism are also enclosed and automatically lubricated with low-pressure oil. The valve spring and rockers are likewise enclosed and the valve clearances are adjusted by eccentric bushes in which the rockers are carried. A special feature of the engine is a system of synchronous automatic spark advance by means of which both systems of ignition are controlled through a centrifugal governor. The latter is arranged to control the oil supply to a small servo-motor which gives ample power to operate the various ignition-control levers.

The arrangement also constitutes a safety device, because the oil for the servo-motor is supplied from the main lubrication system, and should the latter fail the ignition is automatically returned to zero, thus giving warning to the driver.

The single-ended water pump is arranged with a double gland so that oil or grease can be forced into the sealed space between the two packings, forming an effective water lock. (*Engineering*, vol. 119, no. 3098, May 15, 1925, p. 605, 2 figs., *d*)

POWER-PLANT ENGINEERING (See also Air Machinery: Aerodynamo Wind Mill: Steam Engineering: True Efficiency of Impulse Turbines)

The Large Water-Tube Boiler

AFTER reviewing the developments which have taken place in power-station practice in the United States and elsewhere, the author of the paper under consideration was led to suggest that rapid developments were likely to occur in England also, and he predicted, "on official authority," a fourfold growth in England's power requirements during the next ten years, and with a view to obtaining this power as cheaply as possible, it is essential that the boiler-room efficiency should be high. This involves the use of high-powered boilers. The requirements to be met in the design of large boilers are, the author suggests, a capacity of 100,000 lb. to 300,000 lb. of steam per hour, positive immunity from tube troubles, immunity from priming at high duties, high efficiency, boiler and furnace suitable for continuous operation for long periods without stoppages from minor causes; and the design should be such that high working pressures of 500 lb. per sq. in. and upward could be employed. The exact form of boiler which would be capable of fulfilling all these exacting conditions is, of course, not specified, but it is suggested that in view of recent improvements which have enabled the evaporative duty to be increased by 50 per cent, utilizing all available knowledge and experience, there are no insuperable difficulties to be overcome. The question of the respective merits of boilers of the sectional type in which the tubes are connected to headers as against those in which the tubes are connected to drums are considered by the author, but his conclusion is that it will be best for both types to develop side by side until a more decisive stage is reached.

An essential corollary to the design of the boiler is the design of the furnace and the grate. It is obvious that the furnace should possess proper and ample proportions if large quantities of coal are to be completely and efficiently consumed. Recent developments in the design of wide stokers and high-duty grates have already made the construction of the large boiler possible, but there are certain weaknesses in the furnace which have to be overcome, and the author suggests remedies for these. Of the greatest interest as indicating the methods whereby high rates of combustion are to be obtained, is the section of the paper dealing with pulverized fuel. It is suggested that the present encouraging results which have followed the use of pulverized coal may revolutionize the whole science and practice of steam raising from coal. The effect on the design of the furnace is already becoming obvious, but an equally important effect will probably be apparent in the layout of the equipment for storing, handling, and feeding the coal to the furnaces. This, the author asserts, will be to facilitate the introduction of the large-powered boiler unit with higher efficiency and the elimination of the present cumbersome forms of coal- and ash-handling plant, and generally to lead to substantial reductions both in first cost and the subsequent upkeep of boiler plants.

In conclusion, the author utters a word of caution by suggesting that the problems surrounding the introduction of very large units are of too important a character to be assumed by those responsible for any one station. The whole conception requires to be examined and reviewed under conditions in which the widest knowledge and experience should be pooled. This, he suggests, is only possible by setting up a technical committee, constituted in such a way as to have the countenance of the Electricity Commissioners on the one hand and the complete confidence of those who are responsible for large power stations on the other. Some such course as this would relieve any one electricity undertaking from the necessity of making departures or experiments which might not be generally approved. At the same time the lines along which progress should be made

would be settled impartially, and in this way the public interest would best be served. There is much to be said in favor of this suggestion, although we are inclined to doubt the wisdom of the formation of yet another committee which, in the absence of any actual results to guide them, could do little else but make suggestions as to the lines along which progress could be made. It appears to us to be not unlikely that development in the size of boilers will come about gradually, even as it has in the turbine units, as the demand for power in congested areas increases. When it is found by actual experience that boilers of large size can be economically constructed and operated, the builders will be encouraged to design even larger units, and power engineers to install them. (Philip W. Robson. Paper before Institution of Civil Engineers, London, Mar. 24, 1925. Compare editorial in *The Power Engineer*, vol. 20, no. 230, May, 1925, pp. 161–162, *g*)

Stokers vs. Pulverized Coal

A PAPER of a somewhat controversial nature, being essentially a plea for the stoker as against pulverized-coal firing.

The author gives a chart showing that in this country 12,000,000 boiler hp. are fired by stokers (92.5 per cent) and only 200,000 hp. (1.5 per cent) by pulverized coal. He states, moreover, that stokers are being installed at the rate of 750,000 hp. a year.

There have been large developments in stoker engineering, as a comparison of stokers of only a few years ago with modern stokers will show. Among these stokers may be mentioned the stokers at the Kearny Station of the Public Service Production Co. of New Jersey. These Kearny stokers represent the highest state of development of modern stokers, are 24 ft. 10 in. in depth overall, 27 ft. 9 in. in width, and 16 ft. 3 in. high. The rotary ash-discharge pit of the Kearny stoker is almost equal in depth to the length of the old stoker.

In thinking of recent stoker development, the value of this change is not generally realized, and many engineers think that the only development in stoker construction has been in the length. In the modern stoker there is a fundamental principle which has completely changed the velocity of both fuel and air. This has resulted in a very decided change in the scrubbing action between these two elements.

Work is now in progress looking toward the further zoning of a fuel bed, and future developments will probably be more and more confined to portions of a fuel bed rather than to the fuel bed as a whole. For example, the rotary ash discharge has a vertical depth almost as great as the length of our older stokers, making it possible to design a stoker installation so that one of the largest losses in stoker operation will be reduced, namely, the combustible in the ash. The point is that a combustion system must offer quite as much opportunity to the man who wants capacity as to the one who wants efficiency. The stoker of today does just that. The older stoker, on high-capacity runs, necessarily had to burn coal rapidly and get rid of the ash quickly because a single particle of coal had very little time to spend in the furnace.

The higher fuel-burning capacity per foot of furnace width also has made possible the building of high and narrow boilers with many times more heat-absorbing surface per square foot of floor space covered than was previously considered practical. The single long stoker also has a number of important advantages over the shorter double-set arrangement which it is rapidly rendering obsolete. It is naturally easier to operate one stoker than two, less power is required, and there is much lower maintenance. Also, the single stoker gives a continuous fuel bed under practically the entire length of the tubes, eliminating the area of low combustion in the center occasioned by the ash-discharge mechanism necessarily located in this position.

In the original installation at the Hell Gate station, two 14-retort stokers, each 17 tuyeres deep, with a double-roll rotary ash discharge between them, were used under each boiler, having a depth between end walls of 19 ft. 1 in.

In the new installation, a single 33-tuyere stoker with rotary ash discharge takes the place of the two stokers, and while it is much longer than its 17-tuyere predecessor, it reduces the furnace depth between end walls to 15 ft. 6 in.

The author divides recent stoker development into four periods, the second ending with 1920. In the third period high and narrow boilers and long stokers became the rule, while in the fourth period a number of improvements were brought out in the design of new stokers, the most important of these being the velocity of fuel and air in the different zones of the fuel bed. Furthermore, the rotary ash discharge was widely adopted and the design of the stoker came to be varied to control the travel of the coal vertically, in addition to the former exclusive control of horizontal travel.

The author proceeds next to the discussion of the subject of heat losses and heat recovery, and produces diagrams of heat balances in stoker-fired and pulverized-coal-fired plants. As regards the latter, he compares the losses shown by the St. Joseph Lead Co.'s plant with those of the Lakeside Station, both of which are pulverized-coal plants, and from statements made in the technical paper of the U. S. Bureau of Mines comes to the conclusion that the higher thermal results obtained at Lakeside were due to physical heat-

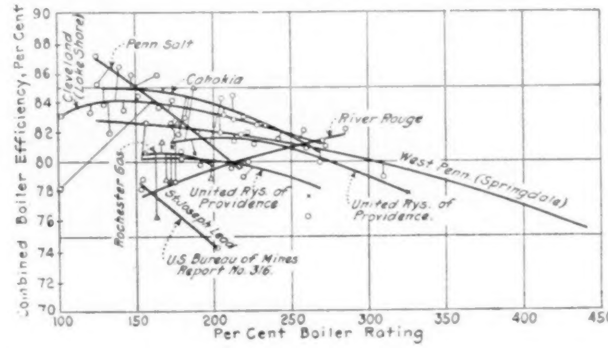


FIG. 6 RELATION BETWEEN EFFICIENCY AND BOILER RATING—PULVERIZED-COAL TESTS

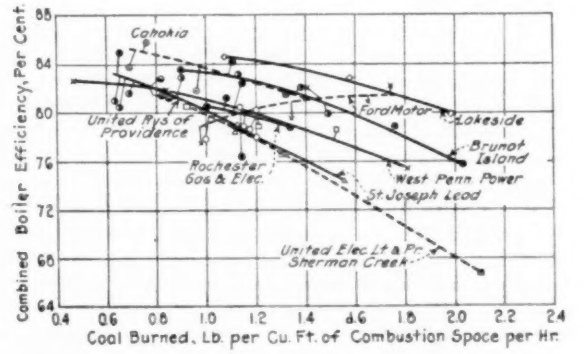


FIG. 7 RELATION BETWEEN EFFICIENCY AND COMBUSTION RATES—PULVERIZED-COAL TESTS

recovery devices rather than to anything that might be inherent in pulverized-coal burning.

He next produces performance curves of modern stokers. In this connection the following quotation is made:

> A paper presented before The American Society of Mechanical Engineers in December, 1924, gives a number of pulverized-coal tests. In an endeavor to find the characteristic performance boiler rating curve, all of these tests were plotted as shown in Fig. 6, giving the relation between efficiency and boiler rating. There seems to be a very wide variation in these results, and the range of operation seems very limited.
>
> This paper, however, did not give any of the results obtained in the tests at the plant of the St. Joseph Lead Company as published by the United States Bureau of Mines, and these tests were plotted because they show the results obtained with pulverized coal with ordinary boiler construction, such as solid brick walls, and with no water screens, no hollow wall construction, no economizer, no heat-recovery advantages, no combustion control, etc. A curve of the Lake Shore plant at the Cleveland Illuminating Company has been added also.
>
> These same results were plotted to show the relation between efficiency and the coal fired per cubic foot of combustion space per hour. The result is as shown in Fig. 7. Still there is no characteristic curve apparent.

As regards comparative tests of stoker and pulverized-coal equipment, the author makes a general statement to the effect that the pulverized-coal equipment is handled with great care and represents the latest developments, while tests on stokers in no case show any similar attempt to secure from them their highest possible efficiency. To show how little reliable information as to the ad-

vantages of the two systems may be derived from such tests, the author gives curves showing side by side the performance of an old stoker and a new one. He also claims that stoker-fired plants can be and are operated at much higher ratings. For example, it is reported that the Lakeside plant at Cleveland (pulverized coal) is operating around 180 per cent of rating, while the monthly average at the Hell Gate plant (stoker) is 237 per cent.

In the discussion which followed, John A. Hunter (Mem. A.S.M.E.), Steam and Sanitary Engr. of the American Sheet and Tin Plate Co., Pittsburgh, Pa., made the following statement:

> This paper is of particular interest to me, because at the Annual Meeting of The American Society of Mechanical Engineers the advocates of powdered coal apparently had everything their way, and would almost persuade one that the stoker was relegated to the scrap heap. I have not become so enthusiastic over the use of powdered coal as to agree with this theory, for I believe (although the use of powdered coal is going to be greatly extended) that for some time, particularly for industrial work and until a great many things in the preparation and firing of powdered coal have been worked out, stokers will still be used.

Sidney J. McAuliffe, Cons. Engr., Gilbert McAuliffe, Ltd., Melbourne, Australia, who has for nearly a year been inspecting power plants in America, came out in the defense of pulverized coal. The author (Jos. G. Worker), in his paper had stated that cement engineers were considering eliminating the use of pulverized coal in kilns. Mr. McAuliffe wondered what they considered adopting in its place and thought that if it was complete gasification there would be two sets of losses instead of one. The flexibility of control of pulverized fuel seemed to be its greatest merit. Furthermore, figures actually obtained on American pulverized-fuel installations of present-day representative efficiency showed an exceedingly small amount of unconsumed carbon in the ashpits. Those interested in pulverized coal, in introducing a new line of thought in combustion, had put decidedly greater technical effort and engineering knowledge and skill into their work than had ever been demonstrated in boiler-room practice of the past. Previous practice had been to sell cast-iron stokers at so many cents per pound. Perhaps it was that kind of practice that had so deeply wounded the stoker interests.

A further statement was made by Mr. Worker, the first part of which is quoted verbatim.

> At the meeting of The American Society of Mechanical Engineers in New York in December, information was asked for as to the cost of maintenance in pulverized-coal plants. Mr. John Anderson, of Milwaukee, in discussing this, stated that his company had been operating a pulverized-coal plant for four years and during this time had pulverized many thousand tons of coal. He stated that any figures given would have to be qualified in one way or another. The result at this meeting was that no figures on the maintenance of pulverized-coal plants were given out. Mr. Anderson's plant has probably been in operation longer than any other pulverized-coal central-station, and if its maintenance figures could not be given as worth anything, no other maintenance figures from more recent pulverized-coal plants would be worth anything for comparison.

In further discussion Mr. McAuliffe made two statements. The first was that in Australia with pulverized coal they had been able to burn 90,000 B.t.u. per cu. ft. of furnace volume in their larger locomotives with water-cooled walls all around the furnace, 16 per cent CO_2 and no CO. The second statement was about a remarkable pulverized-fuel plant which he had seen in America where it was claimed they were actually burning over one-half million B.t.u. per cu. ft. of combustion space with practically no refractory loss in the furnace chambers.

H. W. Brooks (Mem. A.S.M.E.), Fuel Engr., Pittsburgh Experiment Station, U. S. Bureau of Mines, said that he had also seen the new type of pulverized-fuel furnace of which Mr. McAuliffe had spoken. His statement is also quoted verbatim.

> I know the gentleman who is making the tests on it—a former Bureau of Mines man—and, though I have made no tests personally, from his reports and from those of the chief operating engineer of one of the largest public-utility syndicates in the United States under whose direction these tests are being conducted, I sincerely believe the statement that they are burning more than 500,000 B.t.u. per cu. ft. of combustion volume. This, I understand, is roughly forty times what is being done at Lakeside. A real degree of originality is being exercised in these tests. They are following out entirely new lines. It is a most interesting development which gives promise of revolutionary accomplishment.

As regards pulverized coal generally, Mr. Brooks expressed the opinion that pulverized coal was not the panacea for all fuel-burning evils, but a new tool placed in the hands of engineers so that they might develop the proper technique for its most efficient utilization. The proper line of demarkation between the fields for the stoker and for pulverized fuel should be ascertained as speedily as possible, although the rapid developments in both fields since the World War had made the establishment of this division line difficult so far. He further stated that unless such a line was established soon, some concerns might be putting in pulverized coal that might find their needs better served by stokers, and vice versa. A check of the 1923 stoker figures published by the U. S. Department of Commerce as compared with the installations of 1924, showed that there was not a single month during 1924 when the horsepower of stokers installed was as high as in the corresponding month of the preceding year. Pulverized fuel was therefore making a deep impression in the fuel-burning industry.

These figures were questioned by the author, who found that for the two months of October and November, 1924, the sale of stokers exceeded those for the corresponding months in 1923, and that the sale of stokers for 1924 exceeded the reported sale of water-tube boilers.

In conclusion it may be of interest to present a summary of the principal advantages of the modern stoker of the latest design as set forth by Mr. Worker and of pulverized fuel as presented by Mr. Brooks.

Stoker Advantages. 1. Enables more coal to be burned per foot of furnace width. 2. Affords greater length of high-temperature zone. 3. Permits use of high and narrow boilers. 4. Results in more uniform thickness of fuel bed. 5. Gives higher efficiencies at high ratings. 6. Allows greater stoker area to be installed under old boilers. 7. Provides better fuel-bed conditions for high-ash coals. 8. Burns out the fuel more completely. 9. Lowers cost of installation. 10. Does away with double-ended stoker applications, therefore reducing power consumption and maintenance and simplifying operation. 11. Allows entire lower row of boiler tubes to receive radiant heat, reducing furnace temperature. 12. Reduces cost of stoker installation per unit of capacity.

Pulverized-Fuel Advantages. 1. The ability to secure maximum evaporation per pound under wide variations of load factor, fuel, and other conditions. 2. The ability to maintain maximum-capacity conditions over long periods. 3. The ability to meet widely varying capacity conditions with a wide variety of fuels. 4. The ability to maintain practically maximum efficiency over a wide capacity of range. 5. The ability to meet almost instantaneously any sudden peak demands without later interruption to continuous service. 6. The ability to bank over long periods with a minimum fuel loss. (Higher Thermal Results in the Boiler Room, and the Relation between Efficiency and Economic Values, Jos. G. Worker, Mem. A.S.M.E., Asst. to the President, American Engineering Co., Philadelphia, in *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. 41, no. 2, Mar., 1925, original paper, pp. 33–55, and discussion, pp. 56–80, *cpA*)

RAILWAY ENGINEERING

A New Lima Locomotive

Description of a locomotive of the 2–8–4 type with maximum boiler capacity and a four-wheel, booster-equipped, articulated trailing truck.

One of the features of design is the use of two trailer axles and the consequent reduction of weight at the rail with equal spacing of the trailer wheels relative to the rear drive and the front tender wheel. It is claimed that this not only permits improvement in the locomotive itself, but also results in materially improved track reactions.

The weight of the engine alone in working order is 385,000 lb., of which 35,500 lb. is carried on the leading truck, 248,200 on the driving wheels, and 101,300 lb. on the trailing truck. This latter weight is so distributed that 46,600 lb. is carried on the smaller front wheels of the trailer, while the back wheels carry a load of 54,700 lb. It should be noticed that the weight on the rear truck of this engine is much heavier than is common in general practice, and it can readily be seen that such an arrangement permits of a larger boiler and more grate surface than was possible with the use of two-wheel trailing trucks.

As regards the cylinders, they are constructed entirely of cast

steel. All cored passages are eliminated, which makes it possible to produce the cylinders of cast steel with thin walls. Another interesting feature is the arrangement of the front and back valve-chamber heads, and the exhaust-steam passages. Two flanged connections are provided on each of the front valve-chamber extensions, one for the exhaust-steam pipes and one for the pipe which is used for conveying exhaust steam from the cylinders to the feed-water heater. On the back valve-chamber extensions or heads, which also carry the valve crosshead guides, there are flanged connections for the back steam pipes. The exhaust passages are not cast in the cylinders, as is common practice, but instead four exhaust pipes, entirely separate from the cylinders, have been provided. One end of each of these exhaust pipes is bolted directly to the valve-chamber extension and the other to the cylinder casting, where they connect with short passages cored in the cylinders which lead directly to the exhaust nozzle. The saddle, joint faces, frame pads, steam-pipe and relief-valve connections, and the general arrangement are almost identical with those of the usual type made of cast iron.

By constructing the cylinders of cast steel instead of cast iron, their weight was reduced approximately 4000 lb., all of which was used to much better advantage in increasing the size and capacity of the boiler.

The boiler was designed so that at maximum horsepower output the combustion rates would not exceed 100 lb. of coal per sq. ft. of grate per hour, and the rates for average work be far under this figure. It is claimed that this design under normal conditions will operate at a very advantageous efficiency and at the same time provide large reserve capacity for severe and extraordinary conditions.

The boiler is of the extended wagon-top type, $86^1/_2$ in. in diameter, and operates at a pressure of 250 lb. per sq. in.

The firebox is probably the largest ever used on an engine having similar proportions. It is of the radial stayed type, $96^1/_4$ in. wide by $150^1/_8$ in. long, with a grate area of 100 sq. ft. There are five $3^1/_2$-in.-diameter arch tubes in the firebox supporting a sectional brick arch. Flexible staybolts are used throughout in the construction, the first four transverse rows of crown stays being of the expansion type.

The limited cut-off with compensated ports has been applied to this engine because this arrangement at low speeds produces a very uniform turning moment, with the result that a much higher average tractive power for a given driver-wheel weight can be secured than with a full-stroke locomotive. With 240 lb. boiler pressure and 60 per cent cut-off an indicated tractive power of 69,400 lb. has been obtained. The ratio of this tractive power to the weight on drivers is 3.58, which is an unusually low factor of adhesion. The engine, however, is not slippery, because of the even turning moment.

The combination of the boiler pressure and cylinders capable of extremely high horsepower output coupled with a boiler proportioned for generating steam at moderate combustion rates is said to open up entirely new possibilities for locomotive units of greatly increased power and efficiency. (*Railway Review*, vol. 76, no. 18, May 2, 1925, pp. 799–810, illustrated, *dA*)

REFRIGERATION (See also Thermodynamics: The Specific Volume of Superheated Ammonia Vapor: Pressures of Aqueous Ammonia Solutions)

A Refrigerator without Moving Parts

DESCRIPTION of a refrigerator invented by two Swedish engineers, Carl Munters and Baltzar von Platen. For this invention the 1924 Polhem medal was awarded.

The inventors have carried to the desired conclusion researches and inventions by a Frenchman, Carres, and a German, Geppert.

The former aimed at reducing the power required for compression purposes in the ammonia system of heat absorption (i.e., cooling). He still retained a reducing valve, through which the liquid ammonia at higher pressure was expanded at a lower pressure to gas form, thereby seizing upon any available heat and causing the desired refrigerating effect.

Geppert carried the Frenchman's idea a step further and discovered that refrigeration could be obtained without any difference of pressure if the apparatus was filled with a neutral non-absorbent gas, which, by its presence, bridged the pressure gap between the evaporator on the one side and the generator and absorber on the other. Thus Geppert eliminated the compressor and reducing valve but the absorbing liquid (water) required mechanical assistance for its circulation, and a further source of inefficiency inherent in Geppert's design, in which the generator and absorber were combined in one apparatus, necessitated for its partial elimination the introduction of a mechanically driven fan.

The Munters-Platen system is a self-contained apparatus in which the same pressure exists in all parts, and in which heat applied to one portion of an enclosed system produces cold in another portion of the system.

The following is the method adopted, but it should be pointed out that calculations have been made for any combination where:

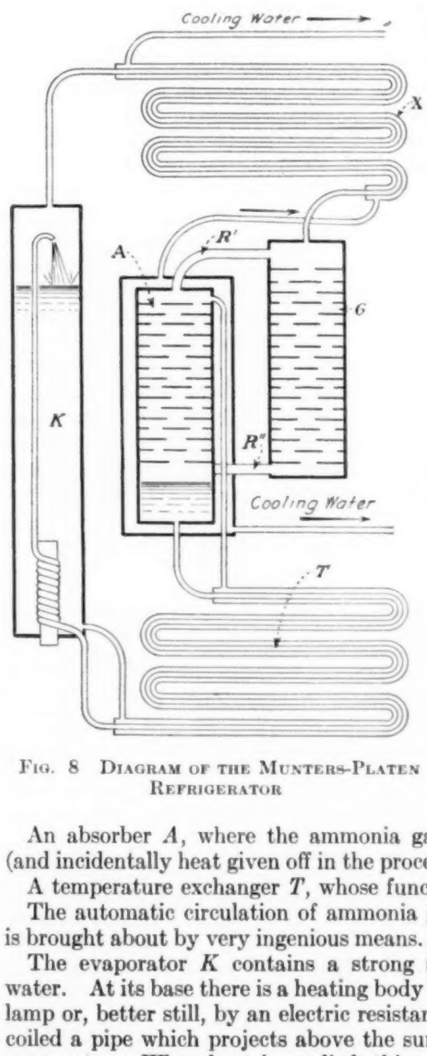


FIG. 8 DIAGRAM OF THE MUNTERS-PLATEN REFRIGERATOR

A is any suitable gasifying medium—in the following description it is ammonia.

B is any absorbing medium—in the following description it is water; and

C is any non-absorbent gas (whether capable or not of being condensed)—in the following description it is hydrogen.

The Munters-Platen apparatus consists of:

An evaporator *K*, in which in this instance a strong solution of ammonia is heated and gives off ammonia gas to—

A condenser *X*, in which the gas is cooled and liquefied;

A generator *G*, in which the liquid ammonia is introduced and gasified by the absorption of heat from its surroundings. *G* is therefore the cooling body;

An absorber *A*, where the ammonia gas is absorbed by water (and incidentally heat given off in the process); and

A temperature exchanger *T*, whose function will be described.

The automatic circulation of ammonia gas and absorbing water is brought about by very ingenious means.

The evaporator *K* contains a strong solution of ammonia in water. At its base there is a heating body which is heated either by lamp or, better still, by an electric resistance. Round this body is coiled a pipe which projects above the surface of the liquid in the evaporator. When heat is applied, this pipe becomes so hot that the water inside it boils, and rising, discharges into the evaporator, and ammonia gas is driven off. By this means ammonia water is continuously drawn from the absorber *A* through the inner coil of the temperature exchanger into the evaporator *K*, and, as stated, ammonia vapor is driven off from it.

We shall now follow the ammonia-gas circulation, and later return to follow the adventures of the water.

Proceeding from evaporator *K* the ammonia gas passes through the condenser *X*, where it becomes liquid and proceeds to the generator (the refrigerating portion), which is filled with oxygen.

In the generator the liquid ammonia, by cooling its surroundings, becomes gasified and mixes with the hydrogen. The resultant gas mixture is heavier than is the pure hydrogen, and therefore the mixture, by reason of its weight, passes through pipe *R''*, into the absorber, where it meets a shower of water. The water absorbs

the ammonia gas, which gives off its latent heat (and cooling of this portion is therefore necessary—it is cooled by water, which later proceeds to the condenser X), and the hydrogen, denuded of its heavier ammonia-gas content, becomes lighter than was the gas mixture, and so rises and passes again into the generator by way of pipe R', and so continues to circulate automatically.

A feature introduced into the actual apparatus as made, but which for the sake of simplicity, is not shown on this diagram, is that pipes R' and R'' are laid one inside the other, forming another temperature exchanger, in order that the cold gas mixture on its way to the absorber may become heated and the warmer hydrogen on its way to the generator may be cooled by the exchange of heat on the contraflow system.

Now, we must return to the question of the circulation of the absorbing agent (water).

The water partly denuded of its ammonia content on entry into the upper part of the evaporator K, is still further denuded of ammonia by the heat applied at the evaporator base. This water flows away by gravity from the evaporator by means of a pipe situated through the outer coil of the temperature exchanger T, being cooled as it proceeds, and enters the absorber A at its upper end. Being relatively free of ammonia it readily absorbs the ammonia gas contained in the ammonia and hydrogen atmosphere existing in A and falls to the bottom of A, being once more a strong solution of ammonia. It is withdrawn from A through the temperature exchanger, being heated as it passes along until once more it passes through the heating coil in the evaporator already referred to, and so, being heated violently, rises and discharges once more into the evaporator. This completes the description of the cycles for the gasifying medium, the absorbing medium, and the non-absorbent gas medium, which are continuous.

It will thus be seen that the only motive force for the whole apparatus which sets these cycles in operation is derived from a heating coil, and that by the application of heat to this one portion the refrigeration desired is obtained in another portion and, as already stated, the pressure in the apparatus is the same in all parts and the whole forms a hermetically sealed system. (R. W. in *The Machinery Market*, no. 1278, May 1, 1925, p. 21, 3 figs., *d*)

SPECIAL PROCESSES

Open Hearth with Furnace Pressure Control

A DESCRIPTION of a process where the control of the incoming and outgoing gases in an open-hearth furnace has been accomplished by the use of two absolutely similar fans capable of acting alternately as blowers of incoming air and exhausters of outgoing gas. It is claimed that a furnace thus handled becomes as nearly as practically possible a balanced furnace, under complete operating control. The process was developed by Mr. Isley of the Morgan Construction Co., Worcester, Mass. The arrangement in addition to the two fans referred to above involves also the use of two short stacks which serve alternately as inlets for atmospheric air and as outlets for the gases of combustion.

With this arrangement air is preheated from atmospheric temperature to about 550 deg. fahr. in the inlet stack. It is then drawn through the blower, passed through the incoming checkers, and supplied to the furnace through simple flue arrangements. The speed of the two fans can be controlled instantly and the required relation then established at the will of the operator. Moreover the reversal of the furnace is almost instantaneous, and it is claimed that nearly two hours are saved in each 24-hour period due to quicker reversals. It is said that an acid-open-hearth unit equipped with this arrangement has been in service in a steel plant in New England for nearly nine months, and appears to have given satisfaction. (F. J. Crolius, Editor, *Blast Furnace and Steel Plant*, vol. 13, no. 5, May, 1925, pp. 190–192, 4 figs., *d*)

STEAM ENGINEERING

The True Efficiency of Impulse Turbines

WHEN designing steam turbines it is usual to base the proportioning of rotors at the given number of revolutions and given head of heat on the "efficiency at the periphery of the wheel" or indicated efficiency. The windage is then subtracted from the turbine output thus arrived at and the difference, less usually small bearing friction losses, etc. is supposed to give the true turbine output.

However, the maximum value of the true efficiency does not in any way coincide with the most favorable indicated efficiency, which makes it desirable to establish the relation between the true and indicated efficiencies.

Let the case considered be that of a single-rim, single-stage impulse turbine. Using the notation of the velocity diagram of Fig.

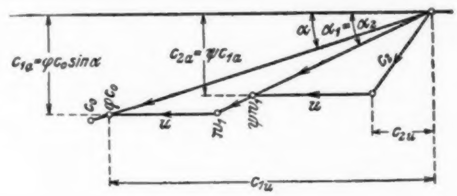


FIG. 9 VELOCITY DIAGRAM FOR A SINGLE-RIM, SINGLE-STAGE IMPULSE TURBINE

9 and assuming that the entrance and exit angles are equal, the indicated efficiency is

$$\eta_i = 2(1+\psi) = \frac{\frac{c_0}{u}\,\varphi\cos\alpha - 1}{\left(\frac{c_0}{u}\right)^2} \qquad [1]$$

This expression shows that η_i for a given angle α depends only on the velocity ratio c_0/u. The windage output of a single wheel, according to tests made at the German General Electric Co., may be expressed in horsepower in the following manner (Stodola, Steam and Gas Turbines, 5th German edition, p. 166):

$$N_r = \left(1 - \frac{B}{\pi D}\right)\beta D^4 L \,\frac{n^3}{10^{10}}\,\frac{1}{v_3} \qquad [2]$$

Here B is the arc of admission in meters, β a constant, D the average blade-wheel diameter in meters, L the length of the blades in centimeters, n the number of revolutions, and v_3 the specific volume of the steam at the exit from the wheel in the cubic meters per kilogram.

Equation [2] may also be expressed in the form of $N_r = f\left(\frac{c_0}{u}\right)$. All magnitudes in what follows are in meters, meters per second, and cubic meters per kilogram (see the equivalents of compound metric units at the end of the abstract). Usually

$$B = \frac{v_1 G_n}{3600\, c_{1a} l}$$

where G_n is the useful steam in kilograms per hour, v_1 the specific volume at the entrance to the blade, and c_{1a} the axial component of c_1. The length of blades at the exhaust from the wheel is $L = l\,\frac{v_2}{\psi v_1}$, where l is the height of the nozzle in meters. If now we insert the values for B and L in Equation [2] the following expression will be obtained for the windage output in horsepower:

$$N_r = \beta\left(1 - \frac{v_1 G_n}{3600\, c_{1a} l}\,\frac{1}{\pi D}\right) D^4\, 100 l\, \frac{v_2}{\psi v_1}\,\frac{n_3}{v_3}\,\frac{1}{10^{10}}$$

The meaning of v_1, v_2, and v_3 as specific volumes of steam is apparent from Fig. 10, as referring to the various points of state. From this it will also appear that in the first approximation it is permissible to set $v_2 = v_3$.

If, however, the windage output be referred not to the total mass of steam G_n kg. per hour, but to 1 kg. per sec., the windage work per second will be expressed in meter-kilograms by the following equation:

$$L_r = \beta\left(100 n^3\,\frac{D^4 l}{G_n v_1} - \frac{100\, n^3 D^3}{3600\,\pi c_{1a}}\right)\frac{75 \times 3600}{10^{10}\psi}$$

It should be noted, however, that

$$v_1G_n = 3600\ \varphi c_0 F_{ea} \sin\alpha$$

where F_{ea} is the axial section at entrance in square meters. From this, after certain transformations, is obtained

$$L_r = \frac{75 \times 10^2 \times 60^3}{10^{10}\pi^3}\ \frac{u^3\beta}{\psi\varphi c_0 \sin\alpha}\left(\frac{Dl}{F_{ea}} - \frac{1}{\pi}\right)$$

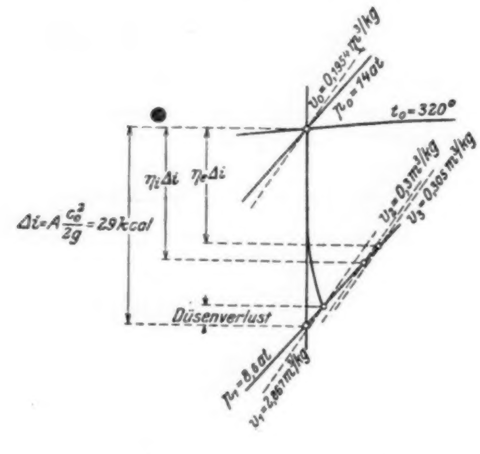


FIG. 10 SECTION FROM THE MOLLIER DIAGRAM
(*Düsenverlust* = Loss in the nozzles.)

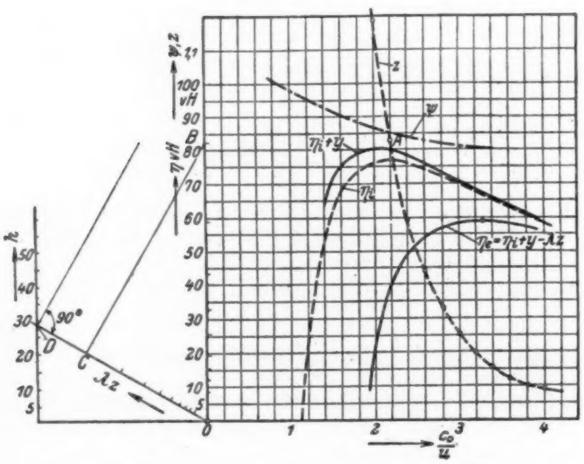


FIG. 11 EFFICIENCY OF A SINGLE-STAGE IMPULSE TURBINE

and with $D = \dfrac{60}{\pi}\left(\dfrac{u}{c_0}\right)\left(\dfrac{c_0}{n}\right)$ this is converted into

$$L_r = \frac{75 \times 10^2 \times 60^3}{10^{10}\pi^4}\ \frac{\beta u^3}{\psi\varphi c_0 \sin\alpha}\left[60\ \frac{l}{F_e}\left(\frac{u}{c_0}\right)\left(\frac{c_0}{n}\right) - 1\right] \ldots [3]$$

The true efficiency expressed by

$$\eta_e = \frac{L_i - L_r}{L_0} = \eta_i - \frac{L_r}{L_0}$$

after the substitution of the value of L_r and certain minor transformations, becomes

$$\eta_e = \eta_i + \frac{\alpha}{\left(\frac{c_0}{u}\right)^3} - \lambda\ \frac{60\ \alpha}{\left(\frac{c_0}{u}\right)^4} \ldots\ldots\ldots\ldots [4]$$

where

$$\alpha = \frac{75 \times 10^2 \times 60^3 \times 2g\beta}{10^{10}\pi^4\psi\varphi \sin\alpha} \quad \text{and } \lambda = \frac{c_0}{n}\ \frac{l}{F_{ea}} \ldots\ldots [4a]$$

In this expression only the member γ [γ does not appear in the actual expression for α.—Ed.] is dependent upon the velocity at exit c_0 and the number of revolutions. Thus, for example, if $\beta = 2.27$, $\varphi = 0.95$, $\psi = 0.9$, and $\sin\alpha = \sin 16$ deg. 42 min.,

$$\eta_e = \eta_i + \frac{0.3}{\left(\frac{c_0}{u}\right)^3} - \lambda\ \frac{18}{\left(\frac{c_0}{u}\right)^4}$$

If Equation [4] be expressed in the form

$$\eta_e = \eta_i + y - \lambda z \ldots\ldots\ldots\ldots [5]$$

where

$$y = \frac{a}{\left(\frac{c_0}{u}\right)^3} \text{ and } z = \frac{60\ a}{\left(\frac{c_0}{u}\right)^4}$$

it will be seen that it is only necessary to plot one $(\eta_i + y)$ curve valid for all values of c_0 and u with $\left(\dfrac{c_0}{u}\right)$ as abscissas, and from this curve read downward the values of z multiplied by γ; this will give the curve of efficiencies. Such a curve has been plotted in Fig. 11; also the z-curve plotted with due consideration of the variability of ψ. These curves are good for all single-rim single stages where $\beta = 2.27$, $\varphi = 0.95$, and $\alpha = 16$ deg. 42 min. The η_e curve has been plotted in the same figure for a special case. It shows how much smaller a peripheral velocity must be selected in order to obtain the most favorable true efficiency than to obtain the indicated efficiency.

In order to reduce the work of reading off the values of λz from the $(\eta_i + y)$ curve, one may resort to the graphic method shown in Fig. 12, which by a simple projection gives the product λz provided

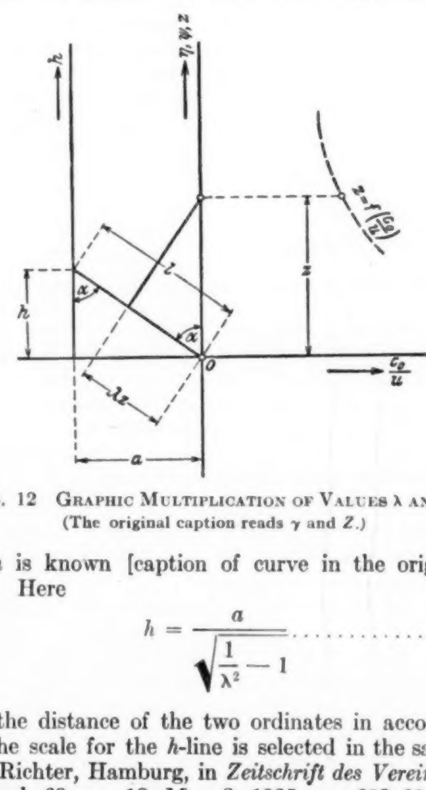


FIG. 12 GRAPHIC MULTIPLICATION OF VALUES λ AND z
(The original caption reads γ and Z.)

the height h is known [caption of curve in the original article states γ/z]. Here

$$h = \frac{a}{\sqrt{\frac{1}{\lambda^2} - 1}} \ldots\ldots\ldots\ldots [6]$$

where a is the distance of the two ordinates in accordance with Fig. 12. The scale for the h-line is selected in the same units as for a. (H. Richter, Hamburg, in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 69, no. 18, May 2, 1925, pp. 603–604, 4 figs., *tp*) (1 meter-kilogram = 7.2330 ft-lb.; 1 cubic meter per kilogram = 16.06 cu. ft. per lb.)

TESTING AND MEASUREMENTS (See also Hydraulic Engineering: Measurement of Velocity of Water Flow)

Codes for Recording Heavy-Oil-Engine Trials

ONE of the objectives of the Heat Engine Trials Committee appointed by the Institution of Civil Engineers some years ago was to formulate codes for recording the results of various engine trials.

A special committee was appointed in due course by the main committee to deal specifically with the tabulation of the results of the heat-engine trials, and a meeting was held at the Institution building in London on May 6, 1925, for the purpose of discussing the standard code drawn up by the latter body to cover heavy-oil-engine trials.

In tabulating the report, the general information and design data are drafted in such a manner that constituent parts not included in the installation to be tested can be deleted. It is not practicable to arrange the code to cover extreme cases of divergence from standard or generally accepted design, but the committee have endeavored to make it sufficiently wide to cover all normal divergences in design. The contents of the code are tabulated in five parts under the respective headings of general information, design data, and detailed description of engine; methods of measurement; mean observations derived from log sheets and preliminary deductions; final deductions; and heat account. The code is accompanied by a comprehensive series of notes for the purposes of instruction and elucidation.

The discussion which took place at the meeting mainly centered on the form of code desirable for industrial tests. It was suggested by several of the speakers that the items on the report marked with an asterisk formed an unnecessarily comprehensive list for many forms of test, and if adhered to would render an ordinary commercial test prohibitive in cost. In this connection, it appears desirable to define the type of engine to which the code is intended to apply. If any engine using a fuel covered by the specifications drawn up by the British Engineering Standards Association for heavy oils is regarded as a heavy-oil engine for purposes of definition, the power may vary between 5 and 500 hp. or over. Small engines which are turned out to standard designs in large numbers are thus included, and it is obvious that the industrial code was never intended to apply to engines of this type. The task of drawing a hard-and-fast line of demarcation appears to us to be impossible, and it is probable that the limit of application of the code can well be left to the manufacturer. The degree of standardization achieved rather than the actual size would appear to be the crucial test, in that it might be desirable to use the code in the case of quite a small engine of new type, but it would become unnecessary to apply it to every engine of the same type turned out after the design became standardized.

It has been also suggested that the results of trials might be divided into three classes based on the power of the engine and that each class might have its appropriate code, but this did not meet with approval. It has been further suggested that the meaning of the term "manufacturers' rating" should be clearly defined because of the variation of these ratings between English and Continental and American firms.

The question as to whether the calorific value of the fuels should be specified as the gross or the net value was discussed at some length. Captain H. Riall Sankey mentioned that this point had received the careful attention of the committee, and that bearing in mind the decision reached by the Boiler Trials Committee, they had desired to adopt the gross value. The main argument in favor of the gross value is that it can be definitely determined by means of an ordinary calorimeter without troubling about the water of condensation, whereas the net value depends upon a correct determination of the latter, and upon chemical estimations which are outside the usual range of engineering practice. In speaking in favor of the use of the gross value, R. H. Parsons pointed out that the use of this value was more logical, as it represented the actual calorific value of the fuel, and although the difference in the two values could not be utilized by the ordinary engine, it was more reasonable to regard this as a failing of the latter rather than as a fundamental fact. More than one speaker expressed the opinion that it was desirable to insert both values in the code, and it was finally agreed that a suggestion to this effect should be made to the committee, with a recommendation that the gross should be regarded as the standard value. A proposal was made by Mr. W. A. Tookey that a note should be appended on this point giving the percentage difference between the two values for computation purposes, and the speaker suggested that this might be taken as 10 per cent in the case of gas and $7^1/_2$ per cent in the case of oil. Mr. Parsons objected that 10 per cent could not be regarded as even an approximate figure in the case of gases containing a large percentage of methane, and it was agreed that it would be necessary to modify the figure in this case. (*Engineering*, vol. 119, no. 3098, May 15, 1925, pp. 611–612, *gA*)

THERMODYNAMICS

The Specific Volume of Superheated Ammonia Vapor

DATA of an investigation carried out at the Bureau of Standards, where a series of observations has been made upon the specific volume of pure superheated ammonia vapor by means of introducing weighed masses of ammonia into a constant-volume gas thermometer of known capacity, and observing temperatures and corresponding pressures.

Adsorption has been either corrected for or proved negligible by taking observations with two or more containers of about the same capacity but of different areas of internal surface.

The observations cover a temperature range from —35 to +300 deg. cent. and were made at specific volumes of from 85.5 to 1300 cu. cm. per gram.

The precision of the observations, except for those at the lowest pressures, is approximately 3 in 10,000. The accuracy is 1 in 1000 or better, and for the higher pressures up to 100 deg. cent., is probably 4 in 10,000.

A modification of the equation which appears in the Bureau of Standards' Tables of Thermodynamic Properties of Ammonia has been adopted to represent the data. The form adopted is the same as has been used to calculate similar metric tables not yet published, and is as follows:

$$V = \frac{4.97881}{p}\,\theta - \frac{3.40645 \times 10^{8}}{\theta^{3}}$$

$$- \frac{(3.6934 + 3.17646p)10^{26}}{\theta^{11}} - \frac{6.0435p^{5}10^{40}}{\theta^{19}}$$

$$+ 10^{-6}(5730.00 - 393.4p + 25.58p^{2} - 0.6077p^{3} + 0.006907p^{4})\,\theta$$

$$- 2.528 - 0.036p$$

In order to obtain consistent tables of the properties of ammonia, the equation is necessarily a compromise between the various data obtained at the Bureau both for saturated and superheated ammonia, and does not represent the data of this investigation with the highest precision. The equation can be modified to agree with all the data on superheated ammonia only, and represent the results of the present investigation within 3 or 4 parts in 10,000. (C. H. Meyers and R. S. Jessup, Assistant Physicists, Bureau of Standards, Washington, D. C., in *Refrigerating Engineering*, vol. 11, no. 10, April, 1925, pp. 345–350 and 354, 4 figs., *egA*)

Total and Partial Vapor Pressures of Aqueous Ammonia Solutions

MEASUREMENTS have been made and experimental values obtained for these pressures. The equations are quite complex and are given in the original paper for total pressure on page 18 and for the relationship between the concentration of the solution and the vapor pressure of the water above that solution on page 29. This latter equation has been used to calculate a table of partial pressures of water vapor above aqua ammonia over a certain range, and from this other tables have been calculated.

The application of the tables and diagrams to the ammonia absorption process is illustrated by employing them in a particular case. (Thos. A. Wilson in *Bulletin No. 146 of the Engineering Experiment Station, University of Illinois*, vol. 22, no. 23, Feb. 2, 1925, 47 pp., 7 figs., *e*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Engineering and Industrial Standardization

The Benefits to Industry Resulting from Standardized Practice[1]

IN its work on industrial standardization the American Engineering Standards Committee has had occasion to compile a fairly complete statement of the advantages which accrue to industry from the adoption of standards. These advantages are the greater with each succeeding stage of development—from standards entirely within a given plant to those prevailing throughout an industry, and finally to those which are national in scope and to a greater or less extent affect nearly all industries.

National standards, as will be seen from the analysis below, afford the advantages named to an enhanced degree as compared with standards accepted only within a given industry. Similarly, as the public appreciation of the value of standardization becomes greater, there will be a stronger and stronger movement toward the development of international standards, such as have already been attained to a considerable degree in connection with ball bearings, and as are now under consideration by a number of countries in respect to sizes of paper, screw threads, and the proportions of bolts and nuts with the corresponding wrench sizes.

For convenience, the gains due to standardization have been more or less loosely classed under four general heads as follows:

Systematizing of business
Enlargement of markets
Better service to the consumer
Reduction of direct and indirect expense.

I—Systematizes Business

1 Standardization expedites business processes, shortens the time required for delivery, and stabilizes production, employment, and financing, making it safe to build up stock during slack times against future orders.

2 It furthers the tendency to put business undertakings on a systematic basis and to eliminate purely traditional practices.

3 It tends to eliminate indecision—both in production and utilization—thereby greatly promoting efficiency and saving time and materials.

4 It favors development work and the quick utilization of new research, by affording a definite point of departure at which new studies and improvements in design and manufacture can begin. It brings out the need of new facts in order to determine what is best and most economical and to secure agreement on most questions.

5 It makes easier and more certain the efficient intermembering and interworking of apparatus and reduces the engineering and operating problems involved in such cases.

II—Enlarges Markets

1 Products manufactured in accordance with standards that are nationally recognized, reach a wide market through the effective and dignified national publicity that is given the standards during their development, the period of public criticism before their adoption, and finally by their adoption as standards. (For example, non-standard fire-hose couplings are known only to the firm making a particular form, and to its limited list of customers and users of the product; whereas fire-hose couplings made in accordance with the American national standard thread design quickly become known to and recognized by architects, owners, and managers of buildings, city, county, and state inspectors and officials, insurance companies, piping contractors, manufacturers of fire-protection equipment, water-works engineers, and other important groups.) By this public recognition of standard products, local use of the product becomes national, and qualities known and accepted in one industry become known and accepted in industry generally.

2 Standardization will build up foreign trade. In gaining recognition for its standards in foreign countries, an exporting country establishes an important point of contact and business outlet for its industries.

3 It simplifies the buyer's problem and raises the standard of salesmanship by focusing attention upon fundamentals. It protects the buyer, who can ordinarily have no first-hand or expert knowledge of the things bought. Furthermore, with standardization, buyer and seller are enabled to speak the same language; and due to the simplification which it affords, of the issues likely to arise, such disagreements as occur can be settled by the interested technical experts, as they should be, without the necessity of resort to the courts. Standardization helps in placing competition upon the basis of essentials and in eliminating minor and irrelevant variation, so saving much time and expense on the part of both the buyer and seller.

4 It simplifies the problem of ordering, since standard material need not be described in detail but may be referred to by a recognized name and a generally accepted capacity or size designation, or number.

III—Better Serves the Consumer

1 Standardization favors interchangeability of parts due to the higher accuracy of standardized manufacture, and so makes possible quick deliveries in adequate volume in emergencies. It assures prompt and satisfactory replacement of parts in making repairs, as fewer items have to be carried in stock; in emergencies such parts can be taken from other machines or equipment not in use at the moment.

2 It increases quality of production due to practical elimination of errors of manufacture and shipment resulting from increased and improved facilities for inspection and test; and due to employment of improved tools, materials, and processes, made possible by reduction in the number of these required and by the saving in overhead expenses; the product at the same time tending toward lower and lower prices relative to the prices obtaining on non-standardized products. Standardization thus makes the best available for the many. Examples are seen in the very high standard quality of incandescent lamps and of copper wire for electrical use.

It furthers efficient coöperation between the units of industry; experience gained in standardization work is of direct value in furthering coöperative endeavor in other technical lines.

IV—Reduces Direct and Indirect Expense

1 Standardization reduces investment in raw materials, semi-finished and finished stock, and repair parts, and simplifies and renders less costly the maintenance, distribution, and inventory of stocks of materials, patterns, molds, jigs, templets, tools, dies, gages, instruments, and special machinery, as well as decreasing the storage equipment, personnel, and space required. It saves a multitude of diverse bids, bills, vouchers, payments, and receipts due to the decreased diversity and number of working materials used; and it permits the salvaging of standard parts from obsolete, rejected, or worn-out tools or equipment, with the result of minimizing losses due to stock depreciation and obsolesence.

2 By fixing good practice, it establishes quality and eliminates the burden of repeatedly designing and setting up machines for the manufacture of similar articles which would better be identical, or substantially so.

3 It decreases unit costs by permitting mass production, thus reducing the number of changes and adjustment of machines required, and permitting continuous employment of personnel, in large measure preventing seasonal unemployment and part-time use of tools and machines. In these and in other ways it simplifies the problem of financing the business.

4 It reduces the number of specially trained workmen required, by reducing the number and variety of processes and operations.

5 It increases output of workers by making possible the appli-

[1] **Prepared by F. J. Schlink, Assistant Secretary, American Engineering Standard Committee, and published in the January, 1925, issue of *The Purchasing Agent*.**

cation of specialized machinery and tools, and results in increased skill and speed of working due to repetitive processes.

6 It decreases the work of personnel in

a Supervision and training of shop workmen, who do not have to become familiar with so many products, tools, and processes.

b Designing and drafting and other engineering of product, by permitting concentration of expert knowledge on a few highly developed lines.

c General administration and management, by making possible more complete and less expensive advance planning and calculation in estimating, scheduling, ordering, recording, and cost accounting; and after manufacture, in conveying, distributing, and shipping of product; testing and inspection; bookkeeping; maintenance, repairs, and operation. It reduces the cost of all these because there being fewer items to keep track of.

d Selling. A standardized product can be sold more readily, as the purchaser is aware of its advantages, can make his selection more rapidly, and has confidence in its quality and performance.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society, for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given interpretations of the Committee in Cases Nos. 481, 491, 492, 493, and 494, as formulated at the meeting of April 24, 1925, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 491

Inquiry: Is it permissible under Par. U-61 to transfer the stampings on steel plate without the authorization of an inspector for such transfer of markings under the power boiler rules?

Reply: It is the opinion of the Committee that the requirement of Par. U-61 regarding the transferring of stamps applies to the cutting of large sheets into smaller ones, as well as laying out. Attention is called, however, to the requirement in the last sentence of this paragraph that the form of stamping shall be such that it can be readily distinguished from the original plate-maker's stamping.

CASE NO. 492

Inquiry: Is the maximum unit working stress of 8550 lb. per sq. in. for brazed vessels applicable in the formula for the calculation of dished heads, when such heads are brazed into the vessel? This would force the manufacturers to use heavier heads for brazed tanks than required for tanks of riveted construction.

Reply: Attention is called to the fact that the maximum unit working stress for brazed vessels as given in Par. U-94 is applicable for the determination of the stresses in the shell where affected by the brazed joint. For the original calculation of the dished head the stresses specified in Par. U-36 are applicable, and the requirement of Par. U-94 applies to the connection of the heads to the shell in the vessel.

CASE NO. 493—(In the hands of the Committee)

CASE NO. 494

Inquiry: Is it permissible in the construction of large riveted vessels for storage of compressed air, to use nozzles of cast-iron construction, riveted to the shell, for 6-in., 8-in. and 10-in. pipe-size connections?

Reply: The Code for Unfired Pressure Vessels does not place any restrictions upon material required for nozzles or connections to such vessels. It is the opinion of the Committee that the use of properly designed cast-iron nozzles riveted to the shells of air tanks will constitute safe practice.

National Government Educates for Engineering

MEMBERS of The American Society of Mechanical Engineers and readers of MECHANICAL ENGINEERING will be interested to know that the National Government has educated for the enneering profession hundreds of men, and still has in training for this profession many hundreds more.

These men are in training in the leading colleges and universities of the country and are scattered from coast to coast. The chief cities in which this training is given, and the number of men being trained for mechanical engineers in these cities, are as follows: Boston, 22; New York, 10; Philadelphia, 19; Washington, D. C., 3; Atlanta, 16; Cincinnati, 9; Chicago, 26; St. Louis, 3; Minneapolis, 16; and San Francisco, 6.

This educating of men for the engineering profession is a part of the work of training and educating the soldiers who served in the American Forces during the World War and who received wounds and disabilities that have prevented them from following the same occupations that they did before the war. This work is now entering upon its last phase and will terminate on June 30, 1926.

The scope of this rehabilitation work by our Government is realized by few. It has been going on since 1918. Nearly 180,000 disabled soldiers, from every section of the country, have been trained for almost every conceivable occupation. Some have been enrolled in practically every university, college, and school in the country, while thousands of others have been trained "on the job" in factories and workshops. More than 92,000 have finished their training and have been declared rehabilitated, and practically all of these have been placed in the kind of employment for which they were trained. Some 25,000 men still remain in training, and, as stated above, several hundreds of these are studying engineering. A large number of these will be declared rehabilitated and ready for employment in this month of June due to their graduation from schools and colleges.

The National Government's work in connection with the rehabilitating of the disabled soldiers is carried on under the auspices of the United States Veterans' Bureau, a separate department of the Government directly under the control of the President.

The men that are being trained for the engineering profession are students in the best schools of the country. Much thought was given by the Bureau to the previous preparation, ability, and suitability of these men for the engineering profession before they were permitted to begin their course of study. The Bureau is proud to report that many of its students of engineering have carried off honor grades in various schools.

It is the duty of the Veterans' Bureau, as provided for under the Acts of Congress affecting this work, to secure employment for the men whom it has trained, and the Bureau feels certain that it is appealing to a most receptive portion of the general public when it asks the members of The American Society of Mechanical Engineers to render coöperation and assistance to the Government in placing the men whom it has educated for the engineering profession.

As the Bureau has branch offices in practically all of the large cities of the United States, effective contact can be made by those interested with any one of these offices. The United States Veterans' Bureau, Central Office, Washington, D. C., solicits correspondence and inquiries from members of the engineering profession who might consider favorably taking into their offices one or more of these deserving men who are ambitious for success in engineering.

FRANK T. HINES,
Brig. Gen.; Director, U. S. Veterans' Bureau.

A.S.M.E. Holds Spring Meeting in Milwaukee

Visits to the Industries of the City, Enjoyable Entertainment, and a Technical Program of Excellent Papers Combine to Make Meeting a Memorable One

THE engineers of Milwaukee were effective hosts to a large group of engineers and operating men during the week beginning May 18, 1925. In addition to the Spring Meetings of the American Society of Mechanical Engineers and the American Society of Refrigerating Engineers, there was a gathering of the Wisconsin members of the National Association of Stationary Engineers and the Midwest Power Show held in the Auditorium which attracted many interested spectators.

The Spring Meeting of the A.S.M.E. was held from May 18 through 21 with headquarters at the Hotel Pfister. The registration was 1127, the largest in several years and all present thoroughly enjoyed the excellent program, which included visits to many of the industrial plants of Milwaukee, a series of enjoyable entertainment events, and a technical program of excellent papers that were well presented and thoroughly discussed.

Entertainment Events

The Hotel Pfister furnished an excellent setting for the entertainment events of the meeting. The spacious lobby permitted an excellent arrangement of the registration headquarters and ample room for the informal gatherings which contribute so much to the success of a meeting. There was a large Reception Committee on hand to welcome the visitors. On Monday evening there was an informal reception at which the Mayor of Milwaukee greeted the guests. This was followed by dancing. An excellent program for the ladies included visits to industrial plants, a musical at the Art Institute, sightseeing trips, a visit to the public museum, and a card party and tea, all of which were enjoyed by the 150 or more ladies present.

Excursions and Plant Visits

The excursions and plant visits at the Milwaukee meeting were very well planned and conducted. On Monday afternoon the visits included a trip to the sewage-disposal plant, the Palmolive Company, and the Phoenix Hosiery Company. On Tuesday afternoon about four hundred members boarded special cars for the Allis-Chalmers plant where luncheon was served. Careful routes had been marked throughout the extensive works and interesting exhibits thoroughly placarded had been moved to the inspection route so that in the time available the visitors had an excellent opportunity to become fully acquainted with the methods of manufacture and the products shown. On the same afternoon other groups visited Eline's chocolate factory, the plant of the Robert A. Johnston Company, and the Milwaukee Vocational School. On Wednesday afternoon excursions were made to the Riverside Pumping Station and the plants of the Vilter Manufacturing Company, the Falk Corporation, and the Kearney & Trecker Company. On Thursday afternoon 350 members were guests at luncheon at the plant of the Nordberg Manufacturing Company. After an inspection of the plant the party was taken to the Lakeside Power Station to see the method of burning pulverized fuel in successful operation there.

Committee in Charge

The arrangements at Milwaukee were planned and conducted by an able Committee under the leadership of the following Executive Committee: Fred H. Dorner, Chairman, Robert Cramer, Secretary, Arthur Simon, Treasurer, W. C. Lindemann, A. C. Flory, C. A. Cahill, J. D. Maurer, W. J. Sando and E. T. John.

Addresses at the Banquet

The feature event of the meeting was the banquet on Wednesday evening, May 20, which was addressed by Dwight F. Davis, Assistant Secretary of War, on the subject of Industrial Preparedness as Insurance against War. Fred H. Dorner, Chairman of the Milwaukee Committee, acted as toastmaster. Ex-Governor Emanuel L. Philipp of Wisconsin, was the first speaker. In his remarks of welcome, he paid tribute to the industrial leadership which had made Milwaukee a great machine-building center. He made special mention of E. H. Reynolds and Bruno Nordberg. From the point of view of the layman, he also emphasized some of the fundamentals upon which successful engineering depends. He told of the need for vision and courage to attack problems by other than the well-known tried-out rules to achieve better results than ever before obtained at lower costs. He also indicated something of the tremendous problems which the engineering profession must solve in reducing the cost of heat and in making power more generally available.

In his address, Secretary Davis emphasized the fact that the United States is not preparing for war but against war, in the belief that preparedness to defend this country is the best assurance that it can have for continuing peace. He pointed out that the officers of the Government and of the War Department do not make war, that war can be declared only by Congress, and that it is the task of the Army to fight wars only after they have been declared, and end them as quickly and successfully as possible.

In describing the plans of the War Department, Secretary Davis outlined the preliminary work being done to call to the country's defense in time of emergency every man, every industry, every resource, and every dollar, for in modern warfare the whole nation is fighting. He described the confusion in this country during the last war because of a lack of any war plan from the industrial-supply standpoint. As a result of these conditions the National Defense Act of 1920 was passed, which placed upon the Assistant Secretary of War the responsibility of planning for the mobilization of all of the industries of the country essential to wartime needs—practically all the business of the country. The first task is to estimate the number of each item of equipment which will be required; the second to determine where these items can be obtained. To facilitate this the country has been divided into fourteen procurement districts, and the requirements are allocated to the districts in accordance with their productive capacity. Secretary Davis also emphasized the tremendous economy in lives, money, and time which industrial war plans will insure. He estimated that if the present plans even in their incomplete state had been in effect in the last war, there would have been a saving of a minimum of five billions of dollars.

In response to Assistant Secretary Davis' address, Dr. William F. Durand, as President of the A.S.M.E., pointed out that the National Defense Division of the Society, with the hearty support and approval of the membership, is working to develop means whereby the A.S.M.E. may fit itself effectively into the details of the problems of industrial preparedness. He expressed the hope that the Society would find itself a real factor in the effective development and ultimate realization of an adequate plan for mobilizing the industrial resources of the nation as the best possible insurance against war.

As a token of esteem the engineers of Milwaukee presented to Dr. Durand at this dinner a painting of an attractive beach scene by Spicuzza, a Milwaukee artist.

The Business Meeting

At the Business Meeting announcement was made of the selection of San Francisco as the meeting place of 1926 and the following codes were read by title: Proposed Standards for Steel Flanges and Flanged Fittings for Maximum Pressures of 250, 400, 600 and 900 Lb.; Proposed Standards for Cast-Iron Screwed Fittings for Maximum Pressures of 125 and 250 Lb.; Proposed Standards for Malleable-Iron Screwed Fittings for Maximum Pressure of 150 Lb.; Proposed Code for Identification of Piping Systems; and Proposed Safety Code for Elevators, Dumbwaiters, and Escalators.

There were several important committee meetings held during the meeting among them being the Main Committee on Power Test Codes, the Boiler Code Committee jointly with the National Board of Boilers and Pressure Vessel Inspectors, and the Finance Com-

mittee with the Chairmen of Administrative Committees. The Special Research Committee on Metal Springs held an extended conference with a thorough discussion of the fundamental principles to be followed in the research program.

Public Hearings

Three public hearings were held during the meeting. The first was on Monday afternoon under the auspices of the Boiler Code Committee when the suggested rules for the care of power boilers were presented for public discussion. F. M. Gibson, Chairman of the Special Committee on the Care of Power Boilers, presided. A number of helpful comments were presented. On Wednesday afternoon the Test Code for Centrifugal and Rotary Pumps and the Test Code for Reciprocating Steam-Driven Displacement Pumps were presented at a public hearing with Fred R. Low, Chairman of the Main Committee on Power Test Codes, as presiding officer. Mr. Low also presided at the public hearing held jointly with the American Society of Refrigerating Engineers on Thursday afternoon, at which the Test Code for Refrigerating Systems was presented, and at these two hearings a number of criticisms were presented which will be reviewed by the Committees arranging the Codes. No fundamental or far-reaching changes were suggested.

Technical Sessions

The papers for the Milwaukee meeting were printed well in advance, either in the special supplement to the May issue of Mechanical Engineering or in pamphlet form for distribution. The careful consideration given to the papers was reflected in the discussion they elicited, and the interest taken in the technical sessions was developed by this thorough preparation of printed matter for the meeting.

Machine Shop Practice Session

The session on Machine Shop Practice, held on Tuesday morning, May 19, under the auspices of the Machine Shop Practice Division, was presided over by R. E. Flanders, Member of the Meetings and Papers Committee of the Division.

Three papers were presented, the first being one on Recent Investigations in Turning and Planing and a New Form of Cutting Tool, by Hans Klopstock, which appeared in the June issue of Mechanical Engineering, p. 474, and is discussed below. The second paper by J. Fletcher Harper, dealt with Defects in Large Forgings; while the third, by Joseph Kaye Wood, embodied a Code of Design for Mechanical Springs. Mr. Harper's paper was published in the May issue of Mechanical Engineering, p. 400; the discussion thereon will appear in a later issue. Mr. Wood's paper, which establishes formulas which he presented at an earlier meeting on a more logical and practical basis, will appear in a later issue together with the discussion.

Discussion of Dr. Klopstock's Paper on a new Form of Cutting Tool

A. L. DeLeeuw[1] submitted a written discussion in which he called attention to a paper[2] he had presented at the 1917 A.S.M.E. Spring Meeting in Cincinnati, in which he had described experiments made in 1912–1913 with a tool in all essentials the same as the one described by Dr. Klopstock. It was regrettable that the American machine-tool industry and the colleges had so completely overlooked the lead he had given them in his paper and later writings and had allowed the credit and the benefits to go to investigators in a foreign country. Dr. Klopstock, however, deserved full credit for his work, even though the original and essential experiments had been made before he began his investigation.

O. W. Boston[3] asked if the accuracy of ± 0.5 per cent mentioned in the paper held with reference to cast iron. Experiments conducted at the University of Michigan had given results widely divergent from that accuracy. The paper stated that the power requirements did not increase proportionately to the chip section but more slowly. In the experiments at the University of Michigan it had been found that the total force varied directly as the chip weight and that it did not increase in direct proportion to the depth of the cut, which led him to believe what had already been pointed out a good many times, namely, that a thick chip was cut more efficiently than a thin one.

James A. Hall,[1] referring to the section of the paper dealing with the formation of a chip, called attention to extremely interesting experiments recently reported to the Institution of Mechanical Engineers' Cutting Tools Research Committee by Dr. W. Rosenhain and A. C. Sturney.[2] These investigators observed three types of chip, the tear, the shear, and the flow type, the first, in which the metal is compressed and the crack starts at the point of the tool and runs in as the chip is being torn off, as he understood it, being the type described by Dr. Klopstock.

R. E. Flanders,[3] who presided at the session, said that the possibility of using the extreme rake angles with the advantages that came from so doing were quite largely conditioned on the rigidity of the structure of the machine itself, and that the more rigid it could be made, the greater the chip production with a given amount of tool durability. This was an important point that tool designers sometimes overlooked.

B. H. Blood[4] said that what impressed him most was the corroboration of the author's experimental results by those obtained in actual practice in the German railroad shops. As to the tool, this type of cutting edge was of greatest value where a crack preceded the point of the tool—where the chip was formed by tearing off—and therefore the real edge of the tool was doing but very little work. That was the ideal condition for long life of the tool.

Mr. DeLeeuw, referring to his experiments, said that while it might not be possible to use for roughing a tool with a very large rake angle, it was nevertheless possible to set the tool in such a way that although its actual cross-section might not present a large rake angle, its virtual acting angle would have a large rake. That, for instance, was the case with an all-shear tool if set at the proper angle, and the results obtained as regarded the kind of chip formed were interesting.

Dr. Klopstock said that it would be more convenient for him to present his closure in writing at a later date.

Hydroelectric Session

L. F. Moody, Vice-Chairman of the Power Division, presided over this session, which was held on Tuesday morning, May 19, under the auspices of the Power Division. Three papers were presented: namely, Mechanical Problems of Hydraulic-Turbine Design, by William M. White; The Parallel Operation of Hydro and Steam Plants, by F. A. Allner; and Mechanical Features Affecting the Reliable and Economical Operation of Hydroelectric Plants, by E. A. Dow. Mr. White's paper was published in the Mechanical Engineering for June, p. 469; those by Messrs. Allner and Dow will appear in an early issue, as well as a précis of the discussion at the session.

Forest Products Session

The Forest Products Session was held on Tuesday morning, May 19, with William Braid White presiding as chairman. The first paper presented was one by P. H. Bilhuber on Material Handling in a Piano Factory, giving the details of the carefully worked-out internal-transportation system of the Steinway plant in New York City. It was discussed by the Chairman, Thomas D. Perry, E. J. Fishbaugh, and S. Madsen.

G. M. Hunt presented both H. F. Weiss's paper on A New Era in Forestry and A. T. Upson's paper on Standardization of Grading Rules for Hardwood Lumber. Mr. Weiss's paper described the methods by which two companies have been able to grow trees for profit and to utilize the lumber and by-products with a minimum of waste. It evoked a lively discussion by the Chairman, S. W. Allen,

[1] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[2] A Foundation for Machine Tool Design and Construction, A. L. De Leeuw. Trans. A.S.M.E., vol. 39, p. 185.

[3] Professor of Shop Practice and Acting Director of Engineering Shops, University of Michigan, Ann Arbor, Mich. Mem. A.S.M.E.

[1] Associate Professor of Mechanical Engineering, Brown University, Providence, R. I. Mem. A.S.M.E.

[2] Reported in *Engineering*, Jan. 30 and Feb. 6, 1925.

[3] Mgr., Jones & Lamson Machine Co., Springfield, Vt. Mem. A.S.M.E.

[4] Hartford, Conn. Mem. A.S.M.E.

T. D. Perry, S. Madsen, J. H. Slater, L. K. Sillcox, J. Garrett, P. R. Hicks, and G. M. Hunt.

Mr. Upson's paper reported the action taken by the Hardwood Consulting Committee and a discussion of plans for the future. A general discussion followed, Chairman White leading and P. H. Bilhuber, E. J. Fishbaugh, L. K. Sillcox and T. D. Perry contributing.

The session continued over to the afternoon, when the Government plan for lumber conservation as stated in the Clarke-McNary Act was taken up. The points of the Act were all brought out by S. W. Allen, who also spoke of the McNary-Woodruff Bill to come up before the next Congress, which authorizes the necessary financial outlay for the carrying out of the provisions of the former Act.

The session closed with a general discussion of methods of reducing waste in wood-using factories, the standardization of hardwoods, the question of applied laboratory work in the wood industries, and the matter of proper education for the boy interested in the principles of high-grade woodworking.

Pulverized-Coal Session

THREE papers bearing on different phases of pulverized fuel were presented at a session under the auspices of the Fuels Division held on Tuesday morning, May 19, with John Anderson, of Milwaukee, in the chair. These were: Boiler Furnaces for Pulverized Coal, by A. G. Christie; Radiation in the Pulverized-Fuel Furnace, by Walter J. Wohlenberg; and A Microscopic Study of Pulverized Coal, by L. V. Andrews. Abridgments of the papers by Professors Christie and Wohlenberg, together with a summary of the discussion thereon, will appear in a later issue of MECHANICAL ENGINEERING. Mr. Andrews' paper appeared in Section Two of the May issue, page 429, and the discussion which it drew forth will be published in a forthcoming number.

The Milwaukee Session

THE Milwaukee Session of the Spring Meeting of the A.S.M.E. held under the auspices of the Milwaukee Committee, was devoted to subjects relating especially to that city. W. F. Durand, President of the Society, presided. John Arthur Wilson read a paper on the Activated Sludge Sewage-Disposal Plant at Milwaukee, in which he gave an account of its general operation and the fundamental principles involved. Some of the engineering features of the plant were discussed by Robert Cramer in an illustrated address on a Critical Study of Heat and Power Requirements of Sewage-Disposal Plants.

F. W. Mohlman[1] presented a discussion of Dr. Wilson's paper covering some of the work done in the pretreatment and filtration of activated sludge in Chicago.

Questions relating to some of the engineering details were asked Mr. Cramer by E. R. McCuiston,[2] who wondered if the dried sludge could be used as a fuel; by A. E. Walden[3] who wanted to know the pounds of coal necessary to dry a ton of sludge; and by R. H. Kent[4] who asked about other methods of aerating the sewage.

In reply to the first question, Mr. Cramer said that because of the low heating value of the dried sludge no attempt had been made to use it as fuel, although burning it to get rid of it had been considered. It was not possible to say definitely how much coal was used in the drying process. In Chicago, about one pound of coal was used for every four pounds evaporated, and estimates for the Milwaukee plant were based on this figure. In regard to aeration, he said that many methods had been tried elsewhere, some of which he described.

President Durand then called upon Mr. Wilson, who made a reply to Dr. Mohlman's discussion and described in greater detail an aerating device used in Sheffield, England.

Following the papers dealing with the sewage-disposal plant, Charles A. Cahill read his paper on Duty Test of Vertical Triple-Expansion Pumping Engines. The pumping engines were two

[1] Chief, Sanitary District, Chicago, Ill.

[2] Manager, Superintendent, Briggs-Shaffner Co., Winston-Salem, N. C. Assoc-Mem. A.S.M.E.

[3] Chief Engineer, Wehr & Walden, Baltimore, Md., Mem. A.S.M.E.

[4] Philadelphia, Pa.

Allis-Chalmers units at Milwaukee, and the trials showed a high performance.

George H. Barrus[1] compared the performances with those of some other engines, reducing everything to a common basis, and showed that the increase in economy was due to the use of higher pressures and temperatures and not to refinements of details.

Robert W. Angus[2] compared the trial with those on an almost identical engine at Toronto, installed in 1906, and as they gave the same efficiency when compared on the same basis, he argued that this type of machine had reached its ultimate efficiency some years ago. He also pointed out what he considered to be the superiority of the turbine-driven centrifugal pump for this purpose. Loran D. Gayton[3] also presented an argument for the centrifugal pump.

In answer to a question by Frank O. Wallene,[4] the author said that the steam-consumption figures included jacket steam. In answer to the proponents of the centrifugal pump he explained that the pumping engines had been decided upon after a careful study of the relative merits of the two types and he did not believe a mistake had been made.

Following an address by Fred H. Dorner on the Economical Advantages of Cities Having Diversified Industries, the session was adjourned.

It is planned to publish abstracts of the papers and a more extended account of the discussion in a later issue of MECHANICAL ENGINEERING.

Materials Session

THIS session was held on Wednesday morning, James H. Herron, Manager of the Society, presiding. Three papers were presented. The first two appeared in Section Two of the May issue of MECHANICAL ENGINEERING and their discussion will be given in abstract in a later issue. These papers were respectively: The X-Ray Examination of Steel Castings, by J. E. Moultrop and E. W. Norris, and Aluminum and Its Light Alloys, by Robert L. Streeter and P. V. Faragher.

The third paper on Stress Concentration Produced by Holes and Fillets, by S. Timoshenko and W. Dietz, will appear in a later issue of MECHANICAL ENGINEERING. The authors attacked a number of practical problems relating to holes and fillets by analytical and experimental methods. Written discussions were presented by the following persons: George F. Swain,[5] T. McLean Jasper,[6] H. F. Moore,[7] and Henry S. Prichard.[8]

In the judgment of Mr. Swain, engineering today is being and has been demoralized by the abuse of mathematics and of testing, and he was not prepared to accept the authors' results as definite. Results obtained by Professors Moore and McLean, on the other hand, were in good agreement with those found by the authors at the Research Laboratory of the Westinghouse Elec. & Mfg. Co. It appeared that certain experimental results bearing on the matter of stress concentration and its effects showed that for any fixed set of conditions the intensification of stress, using endurance limits as an indicator, would vary with the composition of the material and with the heat treatment. According to Professor Moore, a fact of especial interest to the designer was that the use of the formulas of the theory of elasticity for stress intensification, the use of Dr. Timoshenko's formula for holes, and the use of photo-elastic tests on transparent specimens all gave results which were on the safe side as judged by test results. Mr. Prichard, agreeing with the authors, emphasized the usefulness of endurance tests as the most reliable criteria, but said that where there was a deficiency in these, the methods and tables given in the paper should prove very useful.

[1] Consulting Steam Engineer, Boston, Mass. Mem. A.S.M.E.

[2] Professor of Mechanical Engineering, University of Toronto, Toronto, Can. Mem. A.S.M.E.

[3] Engineer Water Works Design, City of Chicago, 402 City Hall, Chicago, Ill. Mem. A.S.M.E.

[4] Wallene Engineering Co., Cleveland, O.

[5] Professor of Civil Engineering, Cons. Engr., Harvard University, Cambridge, Mass. Mem. A.S.M.E.

[6] Engineer of Tests. Fatigue of Metals Investigation, Univ. of Illinois.

[7] Research Professor of Engineering Materials, Univ. of Illinois, Urbana, Ill. Mem. A.S.M.E.

[8] American Bridge Co., Pittsburgh, Pa.

Materials-Handling Session

THE Materials Handling Division held its session on Wednesday morning, May 20, with Harold V. Coes presiding. Four closely related papers were presented, dealing with the economies of labor-saving equipment and with the formulas and computations employed. These papers appeared in Section Two of the May, issue of Mechanical Engineering, pages 403 to 415.

The first paper, that of James A. Shepard and George E. Hagemann, on Formulas for Computing the Economies of Labor-Saving Equipment, was read by Mr. Shepard and elicited several written discussions. J. A. Brown[1] was of the opinion that the question should be handled by other divisions of the Society as well as by the Materials Handling Division, and that the formulas arrived at thus far were unnecessarily complex. James L. Haynes[2] agreed that materials-handling equipment was a most important field in which to begin applying rational tests of economic value, but felt that a still broader interest would be attracted to the Society if the application of such formulas were made in other industrial phases of engineering.

F. O. Hoagland,[3] Chairman of the Standing Committee on Professional Divisions, cited applications of such formulas to machine tools and to equipment for transportation. Applied to component parts of the products of the Saco-Lowell shops, such formulas had proved that it was more economical to discontinue the pouring and machining of gray-iron castings and to substitute parts made of pressed steel. Mr. Hoagland commented favorably on the statement regarding special productive-labor pay roll. F. T. Smith[4] predicted that the working up by the engineer of such careful analytical methods of handling the economics of production would advance him to a more influential position in the industrial world. R. C. Newhouse[5] offered the criticism that the unamortized value of the equipment displaced was not truly a factor in determining the worth of the new equipment, whatever the viewpoint of the accounting department might be.

S. H. Libby[6] deplored the tendency to disparage new equipment and new methods, and also thought it a pity that so much attention was given to ratio of overhead to direct labor. A. E. Holcomb[7] pointed out that in making comparisons of two types of equipment certain types of overhead could not be deducted when a piece of equipment disappeared. C. Roberts[8] questioned the arbitrary value of 10 per cent assigned for depreciation and obsolescence, and inquired as to the relation between obsolescence and depreciation. R. J. Wadd[9] pointed out that the use of these formulas would help the young engineer, particularly when starting out on sales work.

James A. Shepard, who took the chair following the presentation of the papers and written discussions, submitted a written reply and answered queries during the course of the oral discussion. Answering Mr. Brown, he pointed out that the subject was a broad one indeed, but that the work done so far was of indisputable value. He was pleased to see that Mr. Haynes thought the formulas could be applied to a wider field then suggested in the authors' paper. He thought Mr. Hoagland's discussion of particular interest because of the reference to the special productive labor pay roll, and by inference to the labor burden. Without these two

Mr. Shepard amplified Mr. Smith's discussion by saying that the methods suggested would prove practicable for use by engineers in testing their various conceptions and would increase the strength of their recommendations. In regard to the point raised by Mr. Newhouse as to the desirability of employing a valuation for the unamortized value of the old equipment, even when the equipment which was to be replaced was still carried upon the books at considerable value. Mr. Shepard thought that this question was a very debatable one. It would probably be preferable to neglect any unamortized value in the old equipment, even if this might give an incorrect result. The use of K in the formulas for unamortized values of the displaced equipment would, however, tend toward conservatism in evaluation of results.

[1] Contracting Engineer, W. S. Rockwell Co., Brooklyn, N. Y. Mem. A.S.M.E.

[2] Designer, Allen & Billmyre Co., New York, N. Y. Mem. A.S.M.E.

[3] Saco-Lowell Shops, Biddeford, Me. Mem. A.S.M.E.

[4] Industrial Department, General Electric Co. Mem. A.S.M.E.

[5] Chief Engineer, Crushing & Cement Machinery Dept., Allis-Chalmers Mfg. Co. Mem. A.S.M.E.

[6] General Electric Co., Bloomfield, N. J. Mem. A.S.M.E.

[7] Sales Engineer, Koehring Co., Milwaukee, Wis. Mem. A.S.M.E.

[8] Factory Control, Sears Roebuck Co., Chicago, Ill. Mem. A.S.M.E.

[9] Chief Engineer, Shepard Elec. Crane & Hoist Co., Montour Falls, N. Y. Mem. A.S.M.E.

P. E. Stotenbur[1] presented a written statement with regard to the second paper read, An Application of the Formulas for Computing Economies of Labor-Saving Equipment, by George Langford, Jr. He criticized the fact that in the paper the labor burden was not calculated but assumed. He was quite positive that a labor burden did exist with all labor and that while one usually hesitated to apply a burden rate to material-handling labor due to the fact that it was not apparent, could not be seen, and was not used by accountants, nevertheless such a burden should be applied to material-handling labor. Merritt Lum[2] pointed out that if a maintenance charge was set up for the new equipment, it should also be set up for the old equipment. He also wondered whether it was correct to figure the investment charges on a six per cent basis.

In reply to these discussions, the author, Mr. Langford, said that he had arrived at a labor burden of 75 per cent by analogy, using figures in the night wire plant of his company where overhead charges of 85 per cent had been arrived at by the accountants. There was a difference of opinion among accountants as to whether there should be a six per cent or a three per cent charge on capital investment. He had taken the larger figure to be on the safe side. With regard to the maintenance charge on replaced equipment, in the particular case considered in his paper the hand lift trucks had not actually been replaced by the electric truck. It had merely been planned to purchase some, but electric lift trucks had been bought instead.

Mr. Shepard also dealt with Mr. Stotenbur's discussion and said that the general practice of making no allowance for labor burden perpetrated a large error; adding full factory burden as was occasionally done perpetrated a still greater error, and hence estimating the labor burden was the lesser of two evils.

S. Fasting[3] presented a written discussion of the paper by E. H. Lichtenberg dealing with Labor-Saving Equipment in Road Construction. He thought it a remarkable illustration of the extent to which a comparatively simple modification in mechanical equipment might affect the results obtained, that while the two types of pavers seemed to be very much the same, yet in practice the utilization of the return movement of the bucket to spread the cement effected in the usual life of the machine a saving nearly equal to its entire cost.

Mr. Fasting also discussed labor burden, and pointed out that whereas with new equipment there might be fewer laborers, yet it might not be correct to make a smaller allowance for labor supervision. The number of laborers employed might be smaller, yet the allowance for supervision per laborer might have to be greater. In reply to this last point Mr. Shepard combated the assumption generally made that with the reduced working force the supervisory organization would remain intact. This would only be the case if inefficient methods were employed. Maximum efficiency could only result where changes in equipment were followed by suitable changes in the supervisory force.

National Defense Session

THE National Defense Division of the A.S.M.E. and the Chicago Procurement Planning Association coöperated in the conduct of the National Defense Session held on Wednesday morning. The purpose of the Session was to bring together the industrialists and engineers of Wisconsin with the representatives of the procurement branches of the War Department for an exchange of experience gained in the process of perfecting industrial-preparedness plans. Colonel Frank A. Scott, chairman of the A.S.M.E. National Defense Division, presided.

Capt. A. M. Shearer[4] opened the meeting with a brief paper on

(Continued on page 601)

[1] Auditor, Shepard Electric Crane & Hoist Co., Montour Falls, N. Y. Mem. A.S.M.E.

[2] Vice-Pres. H. W. Shaw Co., Chicago, Ill. Mem. A.S.M.E.

[3] Construction Engineer, Shepard Crane & Hoist Co., Montour Falls, N.Y. Mem. A.S.M.E.

[4] Signal Corps, U. S. A.

MECHANICAL ENGINEERING

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Cost of Non-Standardized Products

MR. EARLE BUCKINGHAM'S paper on Engineering Standards which appears in this issue of MECHANICAL ENGINEERING elicited a goodly quantity of discussion dealing with the general procedure of standardizing tolerances and gaging systems. One of the important factors which was emphasized was the desirability of reducing the diversity of hole diameters when ordering from manufacturers. This diversity gives rise to a large amount of unnecessary manufacturing expense. One designer reported fourteen different methods used by as many different purchasers in specifying similar items from the same manufacturer, with resultant high manufacturing cost.

One of the outstanding advantages of standardized products is the possibility of reducing manufacturing expenses by the general adoption of standard tolerance systems with resultant increase in the quantities in which articles may be manufactured and a corresponding reduction in cost. The advantage of standardization centers about quantity manufacture, and the wide adoption of standardized products opens the way to larger manufacturing quantities.

There seems to be a lack of published data on the relative costs of products manufactured in large quantities and similar products manufactured in small lots on special order. The advisability of determining the high costs due to the need for manufacturing to a wide range of specifications was emphasized in the discussion on Mr. Buckingham's paper. Such data would contribute the information needed as the basis for economics of standardization. Investigations to secure these data involve difficult technical questions and require masses of cost figures from modern cost systems in well-equipped shops producing both quantity articles and substantially similar material in small lots. To be comparable on a satisfactory basis the figures on both products should come from the same organization where uniform supervision and engineering are applied to both products.

In his paper on the Standardization of Small Tools,[1] Carl J. Oxford presented an estimate showing that a twist drill differing slightly from one of the customary size costs nearly 500 per cent more than the standard twist drill.

The collection and dissemination of such data would be of great assistance to the standardization movement in that it would encourage the coöperation of industries in standardization and discourage producers from ordering non-standard articles.

Information, however, should be carefully sifted and weighed, and this the A.S.M.E. Standardization Committee is prepared to do. This Committee is preparing to enter into a project to secure the coöperation of manufacturers in this important investigation.

[1] MECHANICAL ENGINEERING, November, 1922.

Tetraethyl of Lead

THE tetraethyl-of-lead situation appears to be developing in a satisfactory manner. A conference was held in Washington on May 20 under the leadership of Surgeon General Cumming of the U. S. Health Service and a committee was appointed to work out a program of tests that would give reliable information as to whether or not gasoline treated with tetraethyl of lead constitutes a danger to those who handle it, such as garage workers and the general public.

From statements in the papers it would also appear that an extensive investigation to supplement preliminary tests has been undertaken by the Bureau of Mines, and that the Chemical Warfare Service is also working along the same lines.

In the meantime the New York *World* has published results of tests made at the College of Physicians and Surgeons of Columbia University in New York City. These, if correctly reproduced, would appear to be decidedly unfavorable to the new fuel.

The subject is of very great and real interest. From all information available it would appear that there can be scarcely any doubt as to the effectiveness of tetraethyl of lead additions in producing an increased output of power from automotive engines, even those not specially designed for the use of this modified fuel. There is every reason to believe that if engines were designed to take proper advantage of the ability of this fuel to operate at higher compressions, the fuel consumption per mile would be cut down very materially. The fuel consumption of gasoline-driven vehicles is becoming so enormous as to endanger materially the adequacy of the visible supplies of oil in the ground. Under these conditions anything that will make a car run two miles on the amount of fuel that it consumes in a mile today is not only of national but, to all practical purposes, of worldwide importance.

The question of danger in the manufacture of tetraethyl of lead is one which may be safely considered as capable of solution. Quite frequently in the past, in the beginning of the manufacture of a new product, accidents have occurred. When at the beginning of the war the Monsanto Chemical Co. of St. Louis started to make aspirin for the first time in the United States, there were several cases of acute poisoning with fatal results. An investigation was made and methods of frequent washing of the hands of the workmen, changing of clothing, etc. were developed which ultimately entirely eliminated the manufacturing dangers. It does not appear that the same could not be done in the manufacture of tetraethyl of lead with proper machinery that would make the process of production automatic and with proper protection of the workman by the use of gloves, masks, intensive ventilation, and the like.

The question of the health of garage employees and the general public is, however, a different matter. The original tetraethyl of lead composition was of such a character that a sticky deposit was formed on the automobile mufflers. Bromine was then added to convert the exhaust products into a floccular material, and unfortunately gave soluble salts as a result. It is now claimed that these salts are particularly easy of absorption into the human body, and are thus likely to increase the danger to the public health.

In this connection attention may be called to a somewhat queer argument in favor of tetraethyl of lead. Some of its defenders state that automobile engines discharge into the atmosphere large amounts of carbon monoxide, which is distinctly poisonous, and yet no one especially objects to it; then why object to tetraethyl of lead? What is lost sight of is that while carbon monoxide is *poisonous under certain conditions*, it is apparently not materially toxic when discharged on the streets, partly because it is lighter than air and tends to rise above the street level, and also because this tendency is assisted by the fact that the automobile exhaust is much warmer than the surrounding air. Furthermore, winds tend to mix the carbon monoxide with the air until its concentration becomes harmless. Finally, in carbon monoxide poisoning there

is no cumulative effect, and such changes in hemoglobin as this gas produces (provided they do not reach the stage of fairly acute poisoning) are permanently eliminated by a few minutes of breathing of pure air.

The situation is entirely different with respect to lead salts. They are obviously heavy enough to accumulate on the ground in the form of a fine dust which winds and traffic will scatter through the air and which will be inhaled. In rainy weather this situation is not dangerous as the salts are soluble and would be washed away. In dry weather, however, they would be taken into the body and as all forms of lead poisoning are apparently cumulative, the poison would stay in the body until it produced its results which might be negligible in the cases of certain individuals and very terrible in the cases of others.

In a way the violent opposition of the press and many of the state governments with respect to the danger of tetraethyl of lead to public health, together with the effect it has had on the very wealthy and powerful companies interested in the manufacture of this substance, shows how far America has advanced politically within the last twenty years.

Early in the present century there were a number of processes and operations that were unnecessarily dangerous to the health and life of workmen and the general public. To cite but an instance, the rod mill of a score of years ago was a place where a week without one or two men being transfixed with the white-hot rods darting from the rolls was an unusual week indeed. Later, however, such mills were reorganized, which not only made them reasonably safe places to work in but increased many times the production per man employed.

There are a large number of industries involving decided danger in operation. It is claimed that three lives are sacrificed for every million tons of coal brought up from the mines. These are, however, dangers of a kind different from those involved in the employment of a material that would be profitable to use but is not of vital importance.

There is another element in the situation which should not be lost sight of. While tetraethyl of lead is the most efficient anti-knock compound known, it is by no means the only one. Denoting the anti-knock value of tetraethyl of lead by 625, that of another substance, diethyl of tellurium, is 250. Tellurium is not available in unlimited quantities, but sources of it in the United States are known, and even should the use of tetraethyl of lead prove to be undesirable on account of danger to health, this other substance might perhaps be temporarily used.

American Air Policy

During a Congressional hearing into the operations of the United States Air Services, Howard Coffin stated his views as to the future air policies of the United States. Excerpts from this statement follow:

Air power is a composite thing. The several elements which enter into its development shape themselves in my mind about as follows:

1 An aroused and active public interest in the whole subject of aeronautics, based not alone upon patriotism and the common national defense but upon a tangible selfish advantage to the individual citizen as well.

2 Permanent aviation committees in both the House and the Senate composed of able men who will devote their energies to a thorough study and understanding of this vitally important subject.

3 Such Federal legislation for the control of aircraft and of air navigation as will minimize uncertainty and risk and encourage capital investment in commercial aviation.

4 A healthy and commercially profitable civil aeronautical industry inclusive of both production and transportation projects, devoted particularly during peace time to the promotion of the public convenience and welfare and forming a great reservoir or reserve of skilled personnel and equipment against any war emergency.

5 A definite, comprehensive, and continuing Federal policy for the furtherance of aeronautical progress in all its various phases, based on a ten-year appropriation and development program.

6 A centralized administrative agency of Federal Government exclusively and definitely charged with full responsibility in execution of all phases of the national air program other than those limited projects having to do with the activities of governmental departments employing aircraft as an auxiliary to major operations within their provinces.

7 The maintenance of Army and Navy Air Services on such basis of constant effectiveness as will permit of adequate expansion in event of war.

We should, under governmental auspices, effect such extension of the air-mail project as will in future provide the United States with a reasonably complete system of airways linking large centers of population and all points of strategic importance for purposes of the national defense. There may thus be provided at Government expense, and in accordance with a definitely coördinated plan, all those aids to air navigation, including port facilities, lighting and signaling devices, charts, weather forecasts, systems of communication, etc., which have for many years been furnished for the encouragement and facilitation of water-borne traffic—all of which, while vitally necessary to any orderly development of commercial air transportation, are clearly beyond the means of any private corporation or individual to install. This network of national airways once in operation becomes available under proper regulation to any individual citizen or civil corporation, and the Government will find no difficulty in contracting with private agencies for the carriage of its mails or the performance of any other service required. Certainly in the early and considerable extension of the air-mail service we have our best hope of a constructive progress toward the upbuilding of our needed air industry—and with a maximum of benefit to every community of the nation and at a minimum drain upon the taxpayer.

A progressive extension of the air-mail service will have the active support of business men, bankers, chambers of commerce, farmers, and of the voting and thinking public generally. No other governmental agency can be effectively used as a popular channel if indirect subsidy for the promotion of civil aviation in the national interest. Every one of the other forms of transportation has had its subsidy. Our Government has aided and safeguarded the navigation of the lakes and coastwise seas. Railways have had their rights of way and quarter-section grants. For motor-vehicle traffic the Federal and state treasuries are expending hundreds of millions of dollars annually in the building of hard-surfaced highways. The analogy of the airway and its landing ports and its aids to air navigation is beyond argument.

In the consideration of the plans for the setting up of a permanent department of the Government for the administration of aerial affairs, care should be taken to insure the continuing and active interest of the people. We must, as I have before said, appeal to the selfish interest of the private individual citizen as well as to his patriotism. In the face of the extraordinary opportunity open to young men in private industry it will become increasingly difficult to interest in governmental service the type most desirable in air work. The physical and mental qualifications for air service call for the very highest type of American youth, and if we hope to enlist the interest of such men a reasonably definite and attractive career through promotion in rank must be provided. The Government will never be able to compete with private industry in terms of financial reward.

Trade-Association Activities Clarified

The legality of certain trade-association activities has been recently sustained by the Supreme Court of the United States in two important proceedings, the outcome of which has been eagerly watched by the business world, as it involved the interpretation of the Sherman anti-trust law in connection with the gathering and distribution of vital business statistical information among the members of industrial organizations.

The two cases tried, those of the Cement Manufacturers' Protective Association, and of the Maple Flooring Manufacturers' Association, were held extremely important because they bore on an activity which might be considered as typical of the great majority of our trade associations.

By a majority decision the court held as legitimate the distribution by trade associations of statistics as to cost of production and of transportation, of volume of production and of stocks on hand, as well as of selling prices maintained. In substance the court held that it was the use to which this statistical information had been put, rather than its character, which had to be considered in deciding whether the Sherman anti-trust law had been violated or not, although the character of use was not without importance. Dissemination of accurate information might be considered essential for the intelligent conduct of business, and it was declared that the Sherman law was certainly not intended to hamper it.

Two Test Cases

The Maple Flooring Manufacturers' Association, representing about seventy per cent of the production, gathered and distributed statistics of production, stocks, unfilled orders, and average sales prices; it published a book giving railroad rates from Cadillac, Mich., to about a thousand points throughout the country, and its members held meetings where statistics and other matters were discussed. According to the majority opinion of the court, these things in themselves do not constitute restraint of trade.

The Cement Manufacturers' Protective Association, in addition to gathering and distributing information of a nature similar to the above, was involved in the question of distributing information regarding specific job contracts. The court ruling was that there

was no violation of law, because it had not been established that contractors suffered but merely that the system protected manufacturers against contractors who might take advantage of such contracts for cement if the market was favorable.

The Majority Opinion

The decision reached was by a divided court, six to three. The majority opinion was delivered by Justice Stone, who, at the request of the Department of Commerce, had given considerable study to the question of trade statistics. In referring to the minority objections the majority opinion held that in precedents quoted by the dissenters clear intent to evade the law was established, while in the cases at issue circumstances were different.

In the opinion dealing with the floor manufacturers' case Justice Stone declared that

> ....by their course of conduct, instead of evidencing the purpose of persistent violations of the law, they have steadily indicated a purpose to keep within the boundaries of legality as rapidly as those boundaries were marked out by the decisions of courts interpreting the Sherman act.
>
> It is not open to question that the dissemination of pertinent information concerning any trade or business tends to stabilize that trade or business and to produce uniformity of price and trade practice. Exchange of price quotations of market commodities tends to produce uniformity of prices in the markets of the world. Knowledge of the supplies of available merchandise tends to prevent overproduction and to avoid the economic disturbances produced by business crises resulting from overproduction. But the natural effect of the acquisition of wider and more scientific knowledge of business conditions on the minds of the individuals engaged in commerce and its consequent effect in stabilizing production and price can hardly be deemed a restraint of commerce, or, if so, it cannot, we think, be said to be an unreasonable restraint, or in any respect unlawful.
>
> It is the consensus of opinion of economists and of many of the most important agencies of Government that the public interest is served by the gathering and dissemination, in the widest possible manner, of information with respect to the production and distribution, cost and prices of actual sales, of market commodities, because the making available of such information tends to stabilize trade and industry, to produce fairer price levels, and to avoid the waste which inevitably attends the unintelligent conduct of economic enterprise.
>
> Free competition means a free and open market among both buyers and sellers for the sale and distribution of commodities. Competition does not become less free merely because the conduct of commercial operations becomes more intelligent through the free distribution of knowledge of all the essential factors entering into the commercial transaction.
>
> #### Business Foresight
>
> General knowledge that there is an accumulation of surplus of any market commodity would undoubtedly tend to diminish production, but the dissemination of that information cannot in itself be said to be restraint upon commerce in any legal sense. The manufacturer is free to produce, but prudence and business foresight based on that knowledge influence free choice in favor of more limited production. Restraint upon free competition begins when improper use is made of that information through any concerted action which operates to restrain the freedom of action of those who buy and sell.
>
> It was not the purpose or the intent of the Sherman anti-trust law to inhibit the intelligent conduct of business operations, nor do we conceive that its purpose was to suppress such influence as might affect the operations of interstate commerce through the application to them of the individual intelligence of those engaged in commerce, enlightened by accurate information as to the essential elements of the economics of a trade or business however gathered or disseminated.
>
> Persons who unite in gathering and disseminating information in trade journals and statistical reports on industry, who gather and publish statistics as to the amount of production of commodities in interstate commerce, and who report market prices are not engaged in unlawful conspiracies in restraint of trade merely because the ultimate result of their efforts may be to stabilize prices or limit production through a better understanding of economic laws and a more general ability to conform to them, for the simple reason that the Sherman law neither repeals economic laws nor prohibits the gathering and dissemination of information.
>
> #### No Conspiracy
>
> Sellers of any commodity who guide the daily conduct of their business on the basis of market reports would hardly be deemed to be conspirators engaged in restraint of interstate commerce. They would not be any the more so merely because shareholders in a corporation or joint owners of a trade journal, engaged in the business of compiling and publishing such reports.
>
> Viewed in this light, can it be said in the present case that the character of the information gathered by the defendants, or the use which is being made of it, leads to any necessary inference that the defendants either have made or will make any different or other use of it than would normally be made if like statistics were published in a trade journal or were published by the Department of Commerce, to which all the gathered statistics are made available?
>
> The cost of production, prompt information as to the cost of transportation, are legitimate subjects of inquiry and knowledge in any industry. So likewise is the production of the commodity in that industry, the aggregate surplus stock, and the prices at which the commodity has actually been sold in the usual course of business.
>
> #### What Would Be Illegal
>
> We realize that such information gathered and disseminated among the members of a trade or business may be the basis of agreement or concerted action to lessen production arbitrarily or to raise prices beyond the levels of production and price which would prevail if no such agreement or concerted action ensued and those engaged in commerce were left free to base individual initiative on full information of the essential elements of their business.
>
> Such concerted action constitutes a restraint of commerce and is illegal and may be enjoined, as may any other combination or activity necessarily resulting in such concerted action, as was the subject of consideration in American Column & Lumber Co. vs. United States and United States vs. American Linseed Oil Co. But in the absence of proof of such agreement or concerted action having been actually reached or actually attempted, under the present plan of operation of defendants, we can find no basis in the gathering and dissemination of such information by them or in their activities under the present organization for the inference that such concerted action will necessarily result within the rule laid down in those cases.
>
> #### Perfectly Legal
>
> We decide only that trade associations or combinations of persons or corporations which openly and fairly gather and disseminate information as to the cost of their product, the volume of production, the actual price which the product has brought in past transactions, stocks of merchandise on hand, approximate cost of transportation from the principal point of shipment to the points of consumption, as did these defendants, and who, as they did, meet and discuss such information and statistics without, however, reaching or attempting to reach any agreement or any concerted action with respect to prices or production or restraining competition, do not thereby engage in unlawful restraint of commerce.

The Cement Case

In the cement case the Government charged that the defendants, through the activities of the association, controlled prices and production in the following manner:

1 By the use of specific F. O. B. contracts for future delivery of cement, accompanied by a system of reports and trade espionage having as its objective the restriction of deliveries of cement under those contracts.

2 By compiling and distributing among the members freight rate books which give the rate of freight from arbitrary basing points of delivery within the territorial area served by the several defendants.

3 By exchange of information concerning credits.

4 By activities of the association at its meetings.

In submitting the Court's opinion in this case Justice Stone said the two essential elements in a conspiracy to restrain commerce were the gathering and reporting of information which would enable individual members of the association to avoid making cement deliveries on specific job contracts which, by the terms of the contracts, they were not bound to deliver, and the gathering of information as to production, price of cement sold on specific job contracts, and transportation costs.

The opinion continued:

> That a combination existed for the purpose of gathering and distributing these two classes of information is not denied. That a consequence of the gathering and dissemination of information with respect to the specific job contracts was to afford to manufacturers of cement opportunity and grounds for refusing deliveries of cement which the contractors were not entitled to call for, an opportunity of which manufacturers were prompt to avail themselves, is not open to dispute.
>
> We do not see, however, in the activity of the defendants with respect to specific job contracts any basis for the contention that they constitute an unlawful restraint of commerce.

Far-Reaching Influence

The two actions were considered by industrial interests throughout the country as test cases, in which the final decisions would govern to a large extent the future business methods and manufacturing and selling operations of some of the greatest corporations.

George T. Buckingham, counsel for the cement manufacturers, called the decision "a landmark in the construction of the anti-trust laws." "This decision will affect hundreds of trade associations throughout the land," Mr. Buckingham said. "It is probably the most momentous opinion on the Sherman act since the famous Standard Oil case of 1912."

On the whole it may be said that the opinions of the court in both instances are generally looked upon as establishing an unusually clear-cut procedure for trade associations.

National Defense Session

(Continued from page 597)

Industrial Mobilization. He was followed by Hobart S. Johnson,[1] who explained the plans which his organization has made with respect to the manufacture of field guns in case of emergency. He pointed out the relation between his organization and that of the Ordnance Department in setting up the preliminary arrangements for such a plan. Colonel E. A. Russell[2] pointed out some of the difficulties which required solution before a broad plan for industrial preparedness could be developed and also indicated the manner in which some of these problems had been solved. Other manufacturers, engineers, and army officers discussed the various problems informally.

Industrial Power Session

UNDER the auspices of the Oil and Gas Power Division a session at the Milwaukee meeting of the A.S.M.E. was devoted to industrial power. Robert Cramer presided. Papers were presented by Arnold Lack and Charles B. Jahnke on Torsional Vibrations and Critical Speeds of Shafts, and by George H. Barrus on a Test of a Uniflow Engine.[3] A brief account of the discussion on these papers follows.

Discussion of Paper by Lack and Jahnke

H. Schreck[4] took exception to the use of the formula by Dr. Geiger for equivalent length of shaft and presented another by Holzer which he had used with success. He said that it would be interesting to know if the observed and calculated critical speeds of the two- and four-cylinder engines agreed. He preferred to compute the location of the node analytically rather than graphically, and did so for the engine of Fig. 13.

J. Ormondroyd[5] wrote that the theory advanced by the authors in the early part of the paper was in no wise adequate for the problem in hand. He criticized several parts of the paper, including the use of Dr. Geiger's formulas for equivalent length. He said that the authors should be praised for bringing the analysis of vibration before American engineers.

In his closure to the discussion, Mr. Jahnke said that while the analytical method advocated by Mr. Schreck was the fundamentally correct one, Mr. Lack and he had found the graphical method satisfactorily accurate for their purposes. He appreciated the criticisms of Mr. Ormondroyd and pointed out that the subject was to be given additional study and review.

Discussion of the Barrus Paper

James B. Stanwood[6] wrote that the author's tests had demonstrated that the non-condensing steam engine was fully established as a recognized element of direct-connected generating sets. He called attention to the flat performance curves and the marked improvement due to the use of superheated steam. He asked what would have been the result on efficiency if the condensate in the jackets had been removed through a trap.

William C. Brown,[7] in answer to Mr. Stanwood's question said that there was little condensation in the jackets, due to the fact that the surfaces were not subjected to exhaust steam. He was of the opinion that the steam engine had not been satisfactorily developed until other types of prime movers had shown the possibility of using the uniflow principle, as illustrated in the turbine; higher pressures and temperatures, as illustrated in the oil engine; multiple cylinders, as illustrated in the gasoline engine, and the kinetic energy of a jet of steam, as illustrated in the steam turbine. He hoped that this engine would be the forerunner of a line of reciprocating engines developed to the highest possible state of efficiency to put them on a par with other prime movers.

[1] Gisholt Machine Co., Madison, Wis.

[2] Chief of Chicago Ordnance District and Chairman of the Chicago Procurement Planning Association.

[3] Published in MECHANICAL ENGINEERING, Part Two, May, 1925, p. 440.

[4] Charge of Design, Combustion Utilities Corp., 8 Bridge St., New York, N. Y. Mem. A.S.M.E.

[5] Motor Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

[6] Consulting Engineer, Secretary, Houston, Stanwood and Gamble Co., Cincinnati, O. Mem. A.S.M.E.

[7] Stumpf Uniflow Engine Co., Inc., Syracuse, N. Y. Mem. A.S.M.E.

Fred R. Low[1] contrasted the performance of the uniflow engine reputed in the tests with the performances of large pumping engines and steam turbines.

James Tribe[2] spoke of his experience with the design of Corliss engines and said that in reality the uniflow worked on the Corliss principle. With engines exhausting at high back pressure, he thought that compression pressures might become excessive in the uniflow engine.

Charles A. Cahill[3] said that the excellence of the uniflow engine lay in the fact that it was the simplest engine built which could produce similar economy. Secondly, he said, came the important fact that the steam-consumption curve was so flat over such a wide range of load. Thirdly, was the ability to make use of pressures up to 300 lb. per sq. in. and high temperatures.

Rudolph Wintzer[4] told of some of the large uniflow engines made by the Nordberg Manufacturing Co.

Steam Power Session

AT THE Steam Power Session of the Milwaukee Meeting of the A.S.M.E., held under the auspices of the Power Division, with Alexander D. Bailey presiding, five papers were presented: Lake Waters for Condensers, by A. G. Christie; The Rational Design of Covering for Pipes Carrying Steam up to 800 Deg. Fahr., by W. A. Carter and E. T. Cope; A Review of Steam Turbine Development, by Hans Dahlstrand; Analysis of Power Plant Performance Based on the Second Law of Thermodynamics, by William L. DeBaufre;[5] and Comparison of Actual Performance and Theoretical Possibilities at the Lakeside Station, by M. K. Drewry. A very brief account of the discussion of these papers follows. More complete accounts of most of the discussions will appear later.

Discussion of the Christie Paper

James Milne[6] wrote that if full advantage were to be taken of the colder water available at certain depths in lakes, intakes would have to be designed so as to have low entrance velocities, as a high entrance velocity would cause the formation of a vortex which would extend upward and draw in water many feet above the intake. He gave some statistics regarding the intakes for the water works of the city of Toronto and the temperature averages for the past ten years.

Robert W. Angus[7] wrote that in making a study of the effect of depth and location on the temperature of the water in Lake Ontario near Toronto, he had found definite evidence of subsurface currents which made an exact prediction about the temperature quite impossible. To secure the deeper water, he pointed out, involved much difficulty and expense in the majority of cases because in the large lakes the bed generally had a gentle slope near the shore, which would make it necessary to locate such an intake as the author proposed at least 3000 ft. from shore.

N. G. Reinicker[8] wrote that one of the power plants of the Pennsylvania Power and Light Company, depended on an artificial lake for condensing-water supply. The maximum depth was 25 ft. The condensing water, he wrote, was recirculated and put back into the lake from a separate discharge canal extending more than half a mile above the plant. It was found that at least 90 per cent of the cooling effect took place at a point where the water passed

[1] Editor, *Power*, McGraw-Hill Co., Inc., 10th Ave. and 36th St., New York, N. Y. Mem. A.S.M.E.

[2] Mechanical Engineer. Allis Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.

[3] Consulting Engineer, Cahill and Douglas, 217 W. Water St., Milwaukee, Wis. Mem. A.S.M.E.

[4] Chief Engineer, Nordberg Manufacturing Co., Milwaukee, Wis. Mem. A.S.M.E.

[5] Published in MECHANICAL ENGINEERING, Section Two, May, 1925, p. 426.

[6] Mechanical and Electrical Engineer, City of Toronto, Toronto, Can. Mem. A.S.M.E.

[7] Professor of Mechanical Engineering, University of Toronto, Toronto, Can. Mem. A.S.M.E.

[8] General Superintendent, Pennsylvania Power & Light Co., Allentown, Pa. Mem. A.S.M.E.

from the canal in a thin sheet over riprap into the lake. Temperature surveys of the lake taken 1 ft. below the surface showed a variation not greater than 2 deg. at any point from the discharge canal to the point where the water was taken into the plant.

C. G. Spencer[1] wrote that now that the importance of determining the thermocline had been demonstrated, he hoped engineers using lake water for condensers would take temperature readings at various depths and publish the data. He also gave some figures on the coal saving in a plant of 270,000 kw. by a reduction of 20 deg. in the temperature of condensing water.

In closing the discussion, the author said that he was glad that Professor Angus had spoken of the attention necessary to the details of design of intakes, a subject which engineers had neglected, and a study of which might result in a reduction of pumping head, lower temperature, and less air in the water.

Discussion of Paper by Carter and Cope

Ralph J. Hinch[2] told of some experiments on pipe coverings carried out by the Commonwealth Edison Co. to determine what influence the maximum temperature, 750 deg. fahr., would have on the conductivity if the coverings were subjected to it for long periods of time.

Glen D. Bagley[3] called attention to the similarity of the method for the determination of the proper thickness of coverings to be used under various conditions of pipe temperature and steam cost and that developed at the Mellon Institute of Industrial Research in Pittsburgh and reported[4] to the Society in December, 1918. He also pointed out that the amount of heat which it was possible to save per square foot of small pipe was greater than for a large one, but that the cost of covering per square foot in the smaller sizes was so much greater that unless the value of the heat units was very high, the proper thickness of covering for maximum economy in the small pipe sizes would always be less than that of the larger.

R. H. Heilman[5] described the methods used by the Mellon Institute for determining the economical thickness of single and compound pipe covering. He said that tests at the Institute had shown differences of only 5 to 15 deg. fahr. between the outside of the pipe and the inside of the covering, depending upon pipe size, thickness of covering, temperature, etc. and that therefore the author's assumption that these temperatures were the same was justifiable.

L. B. McMillan[6] called attention to the statement in Par. 23 that beyond a fairly definite thickness, any additional covering was of very little, if any, value. The Fig. 6 referred to as indicating this did flatten out as the thickness of insulation increased, but the decision as to whether or not that increase in saving was a paying one could not be determined by the shape of the curve.

R. J. S. Pigott[7] pointed out some reasons for using a lesser thickness of insulation, such as the reluctance to increase fixed charges and the greater ease and quickness of manufacture and repair. He also suggested that inasmuch as heat lost from the pipes was absorbed by the air used for combustion, it was not entirely wasted.

E. T. Cope, in closing the discussion, made a plea for further research in determining the absolute thermal conductivity of insulating materials. In answer to Mr. McMillan he said that there had been no intention of using Fig. 6, which had to do with heat saving, as anything more than a step in the solution of the problem of most economical thickness.

As regarded Mr. Pigott's discussion, he pointed out that the great expense in pipe covering was that of labor, which was not increased by extra thickness as two layers would be used on superheated-steam lines in any case. As for the heating of the air, this was being accomplished by means of superheated steam and would not be efficient.

[1] Engineer, McClellan & Junkersfeld, Inc., New York, N. Y. Mem. A.S.M.E.

[2] Commonwealth Edison Co., Chicago, Ill.

[3] Research Engineer, Union Carbide & Carbon Research Labs., Long Island City, N. Y. Assoc-Mem. A.S.M.E.

[4] Trans. A.S.M.E., vol. 40, 1918, p. 667.

[5] Industrial Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa. Jun. A.S.M.E.

[6] Consulting Engineer, Johns-Manville, Inc., New York, N. Y. Mem. A.S.M.E.

[7] Mechanical Engineer in Charge of Design, Stevens Wood, Inc., 120 Broadway, New York, N. Y. Mem. A.S.M.E.

Discussion of the Dahlstrand Paper

A. A. Christie[1] wrote that the authors data on the efficiency of the high-back-pressure turbine at Akron, 75 to 85 per cent, would assist in dispelling the idea still held by some engineers that the high-pressure sections of a turbine were not efficient. The author's proposal to install high-back-pressure turbines in existing plants was interesting and the curves merited close study. Professor Christie pointed out, however, that while this would pay so far as the turbines were concerned, the reconstruction of the boiler plant might easily prove uneconomical. It would seem more advisable to hold the old low-pressure station for stand-by, peak-load service and to design a complete new high-pressure section that could be used on base-load service.

F. T. Johnson[2] wrote of some possibilities of increasing the economy of the power plant, mentioning modifications to improve the efficiency and durability of furnaces, increase in operating pressure and temperature, and maximum practicable use of the regenerative cycle.

E. W. Norris[3] spoke about the new plant at Weymouth, Mass., pointing out that the high-pressure section was designed with a view to great flexibility in its use with the lower-pressure section and in the development of the plant.

Alfred Iddles[4] discussed the use of the high-back-pressure steam turbine for industrial purposes.

E. H. Thompson[5] offered a comparison of Rankine efficiencies, based on initial temperatures of 700 and 1000 deg. fahr., for a series of pressures from 100 to 1200 lb. per sq. in. The table showed the percentage of increase in every case by the the use of the higher temperature, and showed also how the amount of work done in the region of wet steam was decreased.

In his closure the author said that he appreciated that there were more methods of increasing the economy of existing plants than he had mentioned in his paper, which was confined to a consideration of the steam turbine. The more extended use of high-pressure turbines in connection with process steam had been retarded by the fact that high pressures and temperatures had not been available in the past.

Discussion of the DeBaufre Paper

Written discussion of the DeBaufre paper was presented by J. G. Blunt,[6] who said that the author's method gave a much clearer idea of the relative importance of the losses at various stages in the conversion of heat into mechanical work; by R. Eksergian,[7] who made an application of the principle to the firebox of the locomotive; by T. E. Butterfield,[8] who presented an extension to the analysis of the test used by the author; and by J. D. Merrifield.[9]

The Apprenticeship Session

UNDER the auspices of the Committee on Education and Training for the Industries an Apprenticeship Session was held on Thursday morning. The principal paper, A National Apprenticeship Program, by Harold S. Falk, appeared in MECHANICAL ENGINEERING for May, page 416. In addition to a general discussion of apprenticeship and the Milwaukee plan, F. W. Thomas presented a paper on The Place of Railroad Apprenticeships in a National Apprenticeship Plan, and R. L. Cooley discussed The Place of Vocational Schools in the District Apprenticeship Plan. Abstracts of these papers and discussion will appear in a later issue.

Those contributing to the discussion were Dean R. L. Sackett,

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[2] General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

[3] Engineer, Stone & Webster, Inc., 147 Milk St., Boston, Mass. Mem. A.S.M.E.

[4] Chief Power Engineer, Day & Zimmermann, Inc., Philadelphia, Pa. Mem. A.S.M.E.

[5] Editorial Staff, *Power*, McGraw-Hill Co., Inc., New York, N. Y. Mem. A.S.M.E.

[6] Mechanical Engineer, American Locomotive Co., Schenectady, N. Y. Mem. A.S.M.E.

[7] Engineer, Baldwin Locomotive Works, Philadelphia, Pa. Mem. A.S.M.E.

[8] Professor of Engineering, Lehigh University, Bethlehem, Pa. Mem. A.S.M.E.

[9] Chief Engineer, Continental Sugar Co., Fremont, O. Assoc-Mem. A.S.M.E.

who acted as chairman of the session; H. A. Frommelt of the apprentice department of the Falk Corporation; Luther D. Burlingame and Elmer H. Neff of Brown & Sharpe, Inc.; E. E. Sheldon, Supervisor of Training Department, Lakeside Press, Chicago, Ill.; John J. Metz, District Supervisor of Apprentices, Milwaukee Vocational School; Charles R. Gabriel of the E. W. Bliss Company, Brooklyn, N. Y.; Erik Oberg, Editor of *Machinery*, New York; and C. J. Freund, Apprentice Supt., Falk Corporation.

Management Session

THE Management Session was held Thursday morning under the auspices of the Management Division with A. B. Segur, member of the Executive Committee of the Division, as presiding officer, and a paper on Steel Foundry Management was presented by R. A. Bull. Among the matters taken up in the discussion were the relation of the inspection department to the foundry organization and the adaptation of time study to foundry work. An abstract of the discussion will appear in a later issue of MECHANICAL ENGINEERING following an abstract of Mr. Bull's paper.

A report of the Committee on Unnecessary Fatigue in Industry of the Society of Industrial Engineers was also presented at this session. As a result of the discussion on this report those present agreed in the suggestion that the American Engineering Council be asked to urge the need for governmental research on the general subject of fatigue.

Railroad Session

HARRY T. BENTLEY, member of Meetings and Papers Committee of the Railroad Division, presided at the session held under the auspices of that Division on Thursday morning, May 21.

The first paper, on Factors Concerning the Economics of Shopping Steam Locomotives, by L. K. Sillcox, appeared in the May issue of MECHANICAL ENGINEERING, page 419. The subject was discussed from various angles. L. P. Michael[1] pointed out that one of the reasons why the time between shoppings was extended was due to the changes in locomotive design necessitating maintenance work of a nature that could be and was done in the enginehouse. William Joost[2] recommended centralized repair shops for heavy repairs and that small local shops should take care of current repairs. J. A. Anderson[3] recommended thorough overhauling in heavy shops. W. E. Dunham[4] spoke about the importance of stabilized forces. C. G. Corothers[5] stated that the education of the men and of the mechanics had not progressed as rapidly as the improvement in the locomotives. In his closure, the author, Mr. Sillcox, stressed the difficulty of getting the right kind of men to do the work.

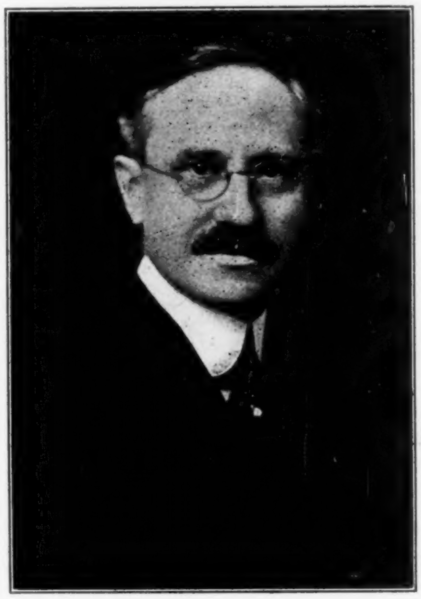
The second paper presented, on Some Freight-Car-Maintenance Problems, by C. G. Juneau, appeared in the June issue of MECHANICAL ENGINEERING, page 457. The author stated that he had endeavored in his paper to bring out some new thoughts on car construction and maintenance of equipment in service. In the discussion, referring to difficulties experienced with air brakes, J. S. Y. Fralich[6] said that the car-maintenance problem was a difficult one, largely because of the conditions under which the men had to work, and that the question of the foundation brake gear required close study, both from the design and the maintenance end. The author, Mr. Juneau, surmised that the great length of the modern train had much to do with the difficulties encountered in the proper functioning of the air brakes. Mr. Dunham[4] suggested that car design, to minimize unproductive parking on repair tracks or elsewhere and to have cars constantly on the road, should conform to the general requirements of the country and follow the general accepted practices of the various railroads. He spoke also of the organization of repair-track and repair-shop forces and of the best allocation of repairs to reap the benefits of specialization. The author heartily agreed with these considerations.

[1] C. & N. W. Ry., Chicago, Ill. Mem. A.S.M.E.
[2] C. M. & St. P. Ry., Milwaukee, Wis.
[3] Shop Supt., C. M. & St. P. Ry., Milwaukee, Wis. Mem. A.S.M.E.
[4] C. & N. W. Ry., Chicago, Ill. Mem. A.S.M.E.
[5] Franklin Ry. Supply Co., Chicago, Ill.
[6] Westinghouse Air Brake Co., Westinghouse Traction Brake Co., Chicago, Ill. Mem. A.S.M.E.

Elbert C. Fisher

ELBERT C. FISHER, vice-president and general manager of the Wickes Boiler Co., Saginaw, Mich., and well known as an engineer and designer of steam boilers, died suddenly on May 18, 1925. Mr. Fisher was born on January 1, 1865, in Scranton, Pa. He prepared for college in the School of Lackawanna, Scranton, and then entered Cornell University, from which he was graduated as a mechanical engineer in the class of 1890.

For one year he worked in the locomotive repair shop of the Delaware, Lackawanna & Western Railroad in Scranton, and then went for a year to Westinghouse, Church, Kerr & Co., in Chicago. For four years he was manager of the Chicago office of the Murphy Iron Works, resigning to become associated with Wickes Bros. in Saginaw, Mich., taking charge of the boiler department and holding that position until 1907 when the present Wickes Boiler Co. was organized and he became its vice-president and general manager.



ELBERT C. FISHER

Mr. Fisher was regarded as one of the country's leading experts in the design and operation of steam boilers. He was long a member of the American Boiler Manufacturers' Association and was honored by election to its vice-presidency. Two years ago he was urged by that organization to accept its presidency, but declined to do so. He became a member of The American Society of Mechanical Engineers in 1891 and attained prominence on the A.S.M.E. Boiler Code Committee, taking a most important part in the difficult work of formulating the first edition of the Boiler Code in 1914. Mr. Fisher served faithfully as member of several of the important sub-committees of the Boiler Code Committee, particularly those involving mathematical research, and he was active in this committee work up to the end. He was one of the managers of the Society from 1919 to 1922 and a member of the A.S.M.E. Council for the same period. He was also an executive of the Board of Boiler Rules for the State of Michigan.

Through his studies in boiler design Mr. Fisher became interested in the problem of water supply, and for several years gave close study to the subject. He was one of the leading advocates of the use of Saginaw Bay water for that city's water supply, and spent an immense amount of time making studies of the bay and other water sources to support his opinion.

Book Notes

ELECTRICAL-MACHINERY ERECTION. By Terrell Croft. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 8 in., 314 pp., illus., diagrams, tables, $3.

Deals with the mechanical features of installation, describing the methods used from the unloading of the apparatus from the car to its final placing and aligning in position for operation. The mechanical maintenance of electrical machinery is also described.

MECHANICS AND HEAT. By William Ballantyne Anderson. Second edition, revised and enlarged. McGraw-Hill Book Co., New York, 1925. (Physics for technical students.) Cloth, 6 × 9 in., 371 pp., illus., diagrams, $4.

A textbook, based on experience as a lecturer and class instructor, in which the practical side of the subject is emphasized. The new edition has the same scope as the earlier one, but a few additional topics and many more problems have been added.

THE ENGINEERING INDEX

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LAST-MINUTE ADDITIONS; MAIN BODY ON PAGE 117-EI, ADVERTISING SECTION

Exigencies of publication make it necessary to put the main body of The Engineering Index into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.